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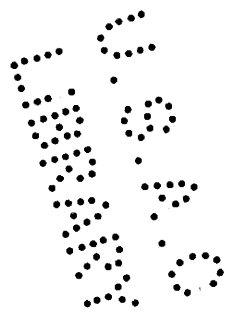
CONSUMPTIVE USE OF WATER STUDIES  
IN THE  
ASILEY AND FERRON CREEK AREAS OF UTAH

by

Elden E Fisher

SUBMITTED IN PARTIAL FULFILLMENT OF THE  
REQUIREMENTS FOR THE DEGREE OF  
MASTER OF SCIENCE  
in  
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1950

UTAH STATE AGRICULTURAL COLLEGE  
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## PREFACE

In January of 1948, a cooperative agreement was prepared between the State of Utah, Office of the State Engineer and the U. S. Department of Agriculture, Soil Conservation Service. This agreement provided for the determination of consumptive use requirements of water in the Colorado River Area of Utah. The representative areas selected for study were the Ashley Valley in the Uintah Basin and the Ferron Creek Area in the Castle Valley. The basic information obtained regarding consumptive use of water will be used primarily as a basis for the allocation of water rights among the various states of the Upper Colorado River Basin.

To assist in making the consumptive use studies in the selected areas, other governmental agencies were invited to participate. These included the Utah Agricultural Experiment Station, U. S. Geological Survey, U. S. Forest Service, U. S. Bureau of Reclamation, and the U. S. Weather Bureau.

The joint agreement proposed that consumptive use of water in the two areas be studied by the "Inflow-Outflow" method and by the "Integration" method. To establish reliable consumptive use data, the following field studies were involved: (a) Streamflow, (b) Ground water, (c) Climate, (d) Land use, (e) Evapo-transpiration tanks, and (f) Soil moisture depletion. The U. S. Geological Survey conducted the streamflow and ground water studies. The U. S. Weather Bureau collected the climatological data. The Soil Conservation Service was responsible for the general supervision of all field studies, in addition to the land use studies. This paper reports only those studies conducted by the

Utah Agricultural Experiment Station, that is, soil moisture depletion and evapo-transpiration studies. Mr. J. Y. Christiansen conducted a similar study during the 1948 growing season. The field study was continued through the 1949 season by the writer. Both of these studies were conducted according to methods proposed by the joint agreement of the cooperating agencies.

E. E. F.



## ACKNOWLEDGMENT

The research studies set forth in this paper were directed jointly by the cooperating agencies. Dr. Dean F. Peterson, Jr. and Professor Cleve E. Milligan of the School of Engineering, Utah State Agricultural College, were responsible for the careful guidance of the study and to whom the writer is deeply indebted. Mr. Willis T. Parrett of the U. S. Department of Agriculture, Soil Conservation Service, furnished valuable advice throughout the progress of the work. Acknowledgment is made of the many favors and courtesies extended by the farmers of the Ashley and Ferron Creek Areas of Utah.

E. E. F.

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## DEFINITION OF TERMS

Some of the terms used in this paper are defined as follows:

Consumptive Use (evapo-transpiration). Consumptive use is the total volume of water used by the vegetative growth of a given area in transpiration or building of plant tissue plus that evaporated from adjacent soil, snow or intercepted precipitation. All terms are expressed in units of depth, feet or inches, for a specified period.

Transpiration. Transpiration is the volume of water absorbed by the crop and transpired and used directly in the building of plant tissue in a specified period.

Evaporation. Evaporation is the process by which precipitation reaching the earth's surface is returned to the atmosphere as vapor.

Unit Consumptive Use. Unit consumptive use is the volume of water used by the plant during the normal growing season, exclusive of evaporation from irrigation and rainfall.

Field Capacity. Field capacity is the volume of water held in the soil after gravitational water has drained away and the rate of downward movement has materially decreased.

Moisture Content. Moisture content is the weight of moisture contained in a given volume of soil.

Moisture Percentage (weight basis). Moisture percentage on a weight basis is the ratio of the weight of water in a given volume of soil to the weight of the dry soil.

Moisture Percentage (volume basis). Moisture percentage on the volume basis is the ratio of the volume of water contained in a given volume of soil to the total volume occupied by the soil.

Apparent Specific Gravity. Apparent specific gravity is the ratio of the

weight of a given volume of dry soil, air space included, to the weight of an equal volume of water.

Mean Temperature. Mean temperature is the arithmetic average of the maximum and minimum temperature as recorded by the weather bureau.

Precipitation. Precipitation is that water which reaches the earth in solid or liquid form.

Relative Humidity. Relative humidity is the percentage ratio of the amount of moisture in a given space to the amount which that volume would contain if it were saturated.

Guttation. Guttation is a process for disposing of water absorbed by the roots in excess of transpiration.

Tank Year. A tank year is considered a crop contained in one tank for one growing period.

## INTRODUCTION

The inadequacy of water and power supplies in Utah for agriculture, for industry, for domestic and community consumption has retarded the State's economic growth. Shortages of water and hydroelectric power are the principal impediments to the full realization of other potentials of Utah, that is, the full use of its arable lands, the wide and diversified use of its industrial raw materials, and the unrestricted development of its communities. The problem of securing additional sources of water and power has resolved itself into one of major concern.

Under the provisions of the Upper Colorado River Compact, Colorado River water will be apportioned to the States involved. The determination of whether each state is getting the apportioned volume allowed by the compact will be based upon consumptive use rather than upon the volume diverted from the river. Consumptive use studies, therefore, are needed as a basis for administration of the provisions of the compact. Moreover, such information regarding consumptive use is needed in planning new irrigation projects (10). These consumptive use studies are to develop unit consumptive use values for the native vegetation and crops grown in the region. Climatic factors are to be observed so that the unit values may be extended to other areas by methods of climatic extrapolation (1). Unit values determined under field conditions by soil moisture depletion methods are superior to unit values obtained by climatic extrapolation from other regions.

### Purpose of Study

The objective of this study was to determine unit values of consumptive use of water by the major crops (alfalfa, small grains, and pasture)



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in the Ashley and Ferron Creek Areas of Utah. The consumptive use by the individual field crops was based on measurements of the depletion of moisture in the soil. Evapo-transpiration tank experiments were conducted in Ashley Valley throughout the growing season and the volumes of water consumed were measured directly. Yield data were obtained from field samples and comparisons between yield and consumptive use were observed.

### Factors Affecting Consumptive Use of Water

Consumptive use of water for a particular area is not a fixed or definite quantity. The volume consumed is influenced by climatic factors, soil characteristics, agricultural practices, irrigation practices, available moisture, and minor factors. The determination of the individual effects, of the various factors on consumptive use, is beyond the scope of this study. Only the combined effect of those factors involved will be considered.

The following discussion, of some of the factors involved, is to indicate the complex nature of such a study and to give a general picture as to how, and under what conditions, the various factors may influence consumptive use. Since consumptive use is often referred to as evapo-transpiration, a brief comment regarding evaporation and transpiration is included.

### Transpiration

Transpiration is essentially the evaporation of water from leaf cells and as such would be expected to be influenced by the same factors which control evaporation from a free water surface. Since soil moisture is the source of water for transpiration, the rate is limited to

the rate at which soil moisture is supplied to the root system. It has been shown (8), that for a certain soil moisture content, transpiration losses are a maximum and that increasing the moisture above this amount does not increase the transpiration. Physiological factors which affect transpiration are density and behavior of the stomata, extent and character of protective coverings, leaf structure and plant diseases. High temperature, low humidity, and strong winds all tend to increase the transpiration unless wilting of the plant occurs.

### Evaporation

The rate at which evaporation takes place is a function of the differences in vapor pressure at the water surface and the air above, the air and water temperature, wind, and to some extent the quality of the water. The nature of the evaporating surface also affects the rate. For example, experiments have shown that evaporation rates from a saturated soil surface are near those from free water surfaces at the same temperature (11). Under certain temperature and moisture conditions during the summer months, evaporation from a soil surface could be expected to exceed that from a free water surface.

### Climatic Factors

Temperature. The rate of consumptive use of water by crops is probably influenced more by temperature than any other factor. Temperature affects the rate at which molecules emit from a water surface, and in general, the higher the temperature, the greater the rate of emission. Formulae have been developed by various men for determining the rate of evaporation based on the heat balance method (8). Hedke (3), in particular, has developed a method of estimating consumptive use by means of heat

units available to a given crop.

Precipitation. Precipitation is one of the main sources of water supply for consumption by plants. Summer rains may add little, if any, moisture to the soil for plant usage due to the high rate of evaporation. In this study, evaporation for each storm was estimated to be 0.5 inches and the soil moisture content was adjusted for storms of greater intensity (4).

Wind. The affect of wind movement is to augment the evaporation rate and thus increase the consumptive use. Wind movement also affects precipitation rates and interception by vegetation. Interception is affected by the wind movement because of the reduction in maximum storage by the plant foliage. In addition, wind movement accompanying a storm may seriously affect gage readings of precipitation depending upon the inclination of the gage to the direction of the wind.

Humidity. Consumptive use of water is a function of the humidity, which in turn, is dependent upon the vapor pressure of the air. The number of air molecules per unit volume increases with increased pressure. Thus, with high pressures, there is more chance that vapor molecules escaping from the water surface will collide with air molecules and rebound into the liquid. Hence, evaporation and consumptive use would be expected to decrease with increased pressure. Also, the volume of water vapor which can exist in a given volume varies with temperature. In arid regions, the typical growing season has hot days and cool nights, which give rise to low and high relative humidities respectively. One would expect the consumptive use to be higher in these regions, since the plants do not have the best conditions to support growth.

### Soil Characteristics

Soil characteristics have been shown to affect the consumptive use of water (7). Soil is a porous medium being composed of soil particles and voids. The voids are filled with air and water, and most of the air retreats to the atmosphere as water is applied. Since plant growth is a function of the soil-air relationship, one would expect heavy clay soil to retard plant growth due to poor aeration, whereas, sandy soils would tend to lose moisture rapidly and thus indicate higher consumptive use values. A soil of high fertility may be expected to produce high yields which would require more water.

### Agricultural Practices

Agricultural practices play an important part in the consumptive use of water (3). In areas where native vegetation is receiving ample water from a high water table resulting in a dense and luxuriant growth, a change to agricultural crops, in general, would decrease the consumptive use. Similarly, an area of native vegetation existing on rainfall only and replaced with an irrigated crop, the consumptive use would increase. In addition, the permeability of the soil may be modified considerably by farming methods such as working the soil while it is wet. This practice tends to decrease the permeability, which in turn, affects the consumptive use.

### Irrigation Practices

Consumptive use is affected by irrigation practices. First use of water, in the production of crops, was solely for the purpose of replenishing moisture in the root zone. While this purpose is still the most important, the use of water for leaching saline soils, and other

beneficial purposes, is becoming general practice. Short irrigation runs, on gentle slopes, permit more economic use of water.

### Available Supply

In areas where the supply of water is plentiful, there is a tendency for over-irrigation both as to frequency and depth of application. Such a practice results in high evaporation losses, which increase the consumptive use.

### Minor Factors

Plant pests and diseases may exert a limited influence upon the volume of water consumptively used. Also, the effect of guttation may result in appreciable losses of water from the plant under favorable conditions of warm humid weather and cool nights (8).

It should be noted, that water requirements for an area are based on the unit consumptive use values as determined for a normal growing season, and are, therefore, subject to irregularities caused by variations from the normal. Allowance must be made for these irregularities.

## Review of Literature

### Methods of Determining Consumptive Use

The problems involved in the determination of unit consumptive use values are numerous. Consequently, several methods have been employed by other investigators. Some of the methods used by others and by the writer are discussed in this section. Experimental data, based on soil moisture depletion studies and evapo-transpiration tank studies, have been used to a large extent for determining unit consumptive use values. Where larger areas, or valleys, are involved, the integration method and the

inflow-outflow method have been used to estimate the valley consumptive use. In some instances, a method developed by Hedke (4) has been used to estimate valley consumptive use based on the heat units available to plant growth.

In the integration method, unit values of consumptive use for each crop are multiplied by the total area of that particular crop. The products obtained, are added to get the total consumptive use of a tract or valley. This method permits determination of the volume of water required for consumptive use of the same type crop in other areas, under similar conditions.

The inflow-outflow method involves the measurement of the volume of water flowing into, and out of a basin over a period of time. The difference between the inflow and outflow, plus an algebraic correction for ground water fluctuation, plus precipitation, equals the volume of water consumed. This method is best adapted to large drainage basins where an overall consumptive use value is desired. It would seem to serve better as a check than as a criterion for estimating consumptive use of water in new areas.

A method suggested by Hedke (4), for estimating consumptive use of water, is based on a linear relation between the volume of water consumed and the quantity of available heat. In view of this assumption, the accuracy of the method appears questionable. Pending further research into the relation of available heat to consumptive use, the method should be used only for comparative purposes.

Soil moisture depletion studies have been used to determine unit consumptive use values. The procedure is to take successive measurements, of the actual moisture content of the soil in the root zone, and

thereby, calculate the volume of water consumed by the crop. The soil samples are taken in foot increments of depth and weighed wet and dry to determine the volume of moisture present in the soil. Special care must be observed in selecting the field plots.

Evapo-transpiration, or tank, experiments have also been used to determine unit values of consumptive use. A measured volume of water is added to field crops growing in a watertight tank containing an undisturbed soil column. The water percolates through the soil and is retained in the tank. Since no water can be lost by deep percolation, all water applied is evaporated or transpired by the crop. Tank experiments are specially adaptable for crops which are subjected to high water table. The depth of the water table in the tank can be maintained to correspond to field conditions, and the consumptive use accurately determined. Actual field growing conditions should be simulated as near as possible in tank studies.

#### Previous Studies

In the studies reported herein, only soil moisture depletion and evapo-transpiration tank experiments were considered. A review of the literature disclosed that consumptive use in other large drainage areas have been studied almost entirely by these methods.

The Division of Irrigation, Soil Conservation Service, have conducted evapo-transpiration studies in various areas of Idaho, for the determination of the consumptive use of water (5). At the Kootenai Experiment Station during 24 tank years, the average use of water by alfalfa was 37 inches or 4.5 acre-inches per ton yield of hay. The average use by wheat, for 66 tank years, was 21 inches or 17.5 acre-inches per ton of grain produced. Oats, apparently high water users, showed a

consumptive use of 27 acre-inches per ton of grain produced. At the Bonners Ferry Station, wheat tanks lost considerable volumes of water by evaporation from the soil surface where the average depth to water was less than 1.75 feet. For water table depths greater than 1.75 feet, the water use per unit of yield was reduced by almost one half.

Studies conducted in the San Luis Rey watershed by Flaney and Muckel, utilized evapo-transpiration data for estimating consumptive use by the integration method (4). The inflow-outflow method was used to check the integration method. For the 13 year period, 1930 to 1943, the average overall consumptive use of 1.42 acre-feet per acre for a normal year as determined by the integration method checked identically with the inflow-outflow method.

Investigations conducted in 1936-1937 in the Upper Rio Grande Basin by the National Resources Committee, involved soil moisture depletion and evapo-transpiration studies (3). The average valley consumptive use, over a 17 year period, of 297,291 acre-feet as determined by the integration method, was almost the same as the average, for the same period, as found by the inflow-outflow method of 297,756 acre-feet. The committee concluded that, if based on careful estimates of unit consumptive use by major agricultural crops and native vegetation and on an accurate distribution of their acreages, the integration method will produce satisfactory results. Also, it was indicated that any error in the estimates of unit consumptive use for a major crop would result in a larger percent error than the same amount of error in the unit consumptive use for a minor crop. The accuracy with which experimental tests on a certain crop should be conducted is a function of its acreage. The Mesilla Valley experiments, conducted over a period of many years, indicate that alfalfa



yield did not increase with increased volumes of irrigation water beyond 4 acre feet per acre.

Soil moisture depletion and evapo-transpiration studies, for the 1948 growing season in the Ashley and Ferron Creek Areas of Utah, were reported by Criddle and Peterson (6). The average unit consumptive use values obtained by the soil moisture depletion studies in the Ashley Valley were as follows; alfalfa 23.6 acre inches per acre, pasture 25.0 acre inches per acre, and small grains 16.6 acre inches per acre. In the Ferron Creek Area, the average unit consumptive use values obtained were; for alfalfa 24.2 acre inches per acre, for pasture 25.5 acre inches per acre, and for small grains 17.8 acre inches per acre. The unit consumptive use values determined by the evapo-transpiration studies in the Ashley Valley were considerably higher than the soil moisture depletion studies indicated.

## DETERMINATION OF UNIT CONSUMPTIVE USE VALUES

For the purpose of this study, the Ashley and Ferron Creek Areas of Utah were chosen as representative areas of the Upper Colorado River Basin. Unit consumptive use values were determined by soil moisture depletion and evapo-transpiration studies in the Ashley Valley and by soil moisture depletion studies in the Ferron Creek Area. The results, from the data obtained in these areas, will be used to estimate the consumptive use requirements of other areas in the basin, as well as a basis for allocating water rights among the upper basin states.

Ashley Valley is located in the northeastern part of Utah and includes all land from the Sign of the Maine, south to the highway bridge crossing the Ashley Creek between the towns of Naples and Jensen, Utah (fig. 7). The principal source of water for the area is the Ashley Creek, however, approximately 6,000 acre-feet per annum is diverted from Brush Creek (6). The Ferron Creek area is located in the central part of Utah on the eastern slope of the Wasatch Range (fig. 8). Nearly all of the water supply is derived from Ferron Creek.

### Soil Moisture Depletion Studies

#### Field Procedure

Soil moisture depletion studies were conducted in the Ashley Creek and Ferron Creek Areas. Suitable sites for depletion studies were limited as water table conditions exist throughout the valleys. Also, in many sections of the Ashley Creek Area, hardpan conditions were encountered at depths ranging from  $3\frac{1}{2}$  to 6 feet. The presence of a hardpan produces a perched water table in some areas. It is impractical to measure the total water consumed by plants when they receive a portion of their supply

from the water table. Figure 7 shows the general location of the 18 field plots in the Ashley Valley and figure 8 shows the location of the 9 field plots in the Ferron Creek Area. The field plots in both areas were located on farms with better than average agricultural practices. They were also located on farms with an adequate water supply. Data obtained on these farms, and under these conditions, are probably more reliable than those data obtained from plots representing average conditions. There is considerable evidence of abandonment of land due to waterlogging and salinity conditions in the lower portions of the Ferron Creek Area. The irrigation companies report a deficient water supply during most of the growing season for an average year. Thus, the unit values of consumptive use as determined are undoubtedly higher than the actual mean consumptive use values for the valley. Unit consumptive use values obtained for the Ashley and Ferron Creek Areas are shown in tables 1 and 2 respectively.

All soil samples were taken with the modified King soil tube at definitely established points in the field plot. The sampling was done in one foot increments to the depth of the root zone. The soil samples were taken to a depth of 7 feet for alfalfa, and to a depth of 5 feet for pasture and small grains. Samples were taken before and after the irrigations. Additional samples were taken between irrigations at, approximately, eight day intervals.

#### Laboratory Procedure

Standard laboratory methods were employed in the determination of moisture percentages. The samples were weighed wet and then dried in an electric oven at 110° C. and the dry weights determined. The volume of water, contained in each foot of soil, was determined from the moisture

Table 1. Results of soil moisture depletion studies in Ashley Valley, Utah 1949.

Crop	Field Plot Designation (Fig. 7)	Consumptive Use (Inches)	Average Consumptive Use (Inches)	Yield	Soil 1/ Classification	Remarks
Alfalfa	A1a	28.4	32.5	4.9T/ac	Redfield F.S.L.	
	A2a	35.8		---	Mesa F.S.L.	
	A3a	34.5		5.4T/ac	Billings clay	
	A4a	31.3		5.1T/ac	Billings clay	
Pasture	A1p	32.2	33.3	---	Billings clay	Wtr. Table 4'
	A2p	31.0		---	Billings clay	Wtr. Table 4'
	A3p	36.7			Billings clay	
Barley	A1b	17.8	19.1	106Bu/ac	Redfield clay	
	A2b	20.3		80Bu/ac	Billings clay	
Corn	A1c	20.8	21.1	14 T/ac	Billings clay	Yield was estimated
	A2c	23.6		21 T/ac	Redfield clay	
	A3c	18.9		10 T/ac	Redfield F.S.L.	
Wheat	A1w	16.3	20.4	50Bu/ac	Billings clay	Wtr. Table 5'
	A2w	24.4		54Bu/ac	Redfield F.S.L.	Partial wtr. supply
	A3w	15.4		44Bu/ac	Mesa F.S.L.	
Oats	A1o	17.6	19.8	---	Billings clay	
	A2o	20.8		65Bu/ac	Billings clay	
	A3o	21.0		65Bu/ac	Billings clay	
Average for small grains			19.7			

1/ From "Soil Survey in Ashley Valley, Utah" U.S.D.A.

140686

Table 2. Results of soil moisture depletion studies in Ferron Valley, Utah 1949.

Crop	Field Plot Designation (Fig. 8)	Consumptive Use (Inches)	Average Consumptive Use (Inches)	Yield	Soil <sup>1/</sup> Classification
Alfalfa	F1a	28.4	31.2	4.7T/ac	Fine Sandy Loam
	F2a	32.7			Medium Sandy Loam
	F3a	32.7			Medium Sandy Loam
Pasture	F1p	30.1	30.1	---	Medium Sandy Loam
Barley	F1b	19.2	19.2	---	Medium Sandy Loam
Corn	F1c	18.8	18.8	---	Medium Sandy Loam
Wheat	F1w	18.1	19.0	69Bu/ac	Fine Sandy Loam
	F2w	19.4		39Bu/ac	Medium Sandy Loam
	F3w	19.5		40Bu/ac	Sandy Loam
Average for small grains			19.0		

<sup>1/</sup> Classified by the writer.

percentages by means of the formula,  $D = \frac{MVd}{100}$ , where D is the equivalent depth in acre-inches per acre, M represents the moisture percentage on a dry weight basis, V is the apparent specific gravity, and d is the depth of the soil in inches.

#### Analysis of Soil Moisture Depletion Data

The soil moisture depletion rates and accumulative consumptive use curves are given in Appendix B (figs. 9-34). The accumulative use curves for each type crop has a characteristic S-shape. Only those plots are included which had a full water supply. Plot A3w received only one

irrigation during the entire growing season and was deleted. Evaporation losses from the water surface during irrigations were excluded. Also, it was assumed that any storm of less than 0.5 inches of rainfall, over a two week period, would be intercepted and evaporated, and would not add to the soil moisture content (4).

Large discrepancies were noted in the dry weights for the same increment of soil depth for successive samples. These discrepancies resulted in variations of apparent specific gravity for a given plot, which directly affected the volume of water computed for the sample. Corrections were applied to the given values of dry weight based on the ratio of the average dry weight to the actual dry weight as determined for each sample. The average dry weight was determined from all samples taken from a given plot throughout the season. It was observed that samples taken when the soil was near field capacity showed considerable less dry weight of material than when the sample was taken at low moisture contents. Under these conditions, a full core was not obtained with the modified King soil tube. The computed volume of water for the sample taken at a high moisture content was less than the volume actually in the soil, had the entire core been obtained. In the case of the sample taken at low moisture content, there was relatively more water as shown by computation than there actually was in the soil. The net result indicated less moisture depletion than actually occurred. From the foregoing observation, it appears that the correction on the basis of dry weights was justified.

Further analysis of the results obtained in Ashley Valley for consumptive use values, indicates that weighted ratios are justified for the pasture and wheat plots. The effect of the water table on the computed net moisture depletion is to give less depletion than actually occurs.

Any use, from the water table depth, by the plant would not be included. In the case of pasture, two of the three plots had a water table at the 4 foot depth. The depth of water table for the third plot was known to be below 32 feet. By arbitrarily assigning weights of 1 and 2, respectively, to the plots with high and low water table, a better estimate of unit consumptive use value was obtained. The weighted unit consumptive use value was 34.2 acre-inches per acre as compared to the average unit consumptive use value of 32.3 acre-inches per acre. The same reasoning applied to the wheat data in Ashley Valley gives a weighted unit value of 21.7 acre-inches per acre as compared to the average unit consumptive use value of 20.4 acre-inches per acre.

The total unit consumptive use of water over the entire growing season is required to obtain the unit consumptive use values utilized in the integration method. From the climatological records and farmers testimonies, it was estimated that the consumptive use by alfalfa and native vegetation began in the middle part of April. The growing season had been in progress for approximately two months before any field samples were taken. Thus, it was necessary to extrapolate for the soil moisture depletion over this early period. Following is a list of the assumptions made in the analysis of each field plot.

#### Ashley Valley Assumptions

Small grains and corn: General assumptions

1. Consumptive use began on the planting date.
2. The plot was at field capacity on the planting date.
3. The plot was at field capacity 2-4 days after irrigation.
4. Dry weight of the core material for each individual plot was constant.
5. The depletion rate during the irrigation period was the average of the prior and following rate.

Individual field plot assumptions:

Plot A1b. Field capacity was 21.3 acre inches per acre.

Plot A2b. Field capacity was 16.0 acre inches per acre.

Plot A1c. Field capacity was 17.3 acre inches per acre.

Plot A2c. Field capacity was 20.3 acre inches per acre.

Plot A3c. Field capacity was 18.5 acre inches per acre.

Plot A1w. Field capacity was 16.6 acre inches per acre.

Depletion rate from planting date to 1st irrigation was  $\frac{1}{2}$  June 15 rate.

Plot A2w. Field capacity was 20.0 acre inches per acre.

Plot A1c. Field capacity was 20.5 acre inches per acre.

Depletion rate from planting date to 1st irrigation was  $\frac{1}{2}$  June 15 rate.

Plot A2c. Field capacity was 19.4 acre inches per acre.

Extrapolated depletion rate was same as required by plot A3c.

Plot A3c. Field capacity was 18.0 acre inches per acre.

Depletion rate from planting date to 1st irrigation was  $\frac{1}{2}$  June 15 rate.

Alfalfa: General assumptions

1. Consumptive use began April 15th.
2. Plot was at field capacity on April 17th.
3. The plot was at field capacity 2-4 days after irrigation.
4. The dry weight of core material for each individual plot was constant.
5. The depletion rate during irrigation period was average of prior and following rate.
6. The growing season ended November 5th.



Individual field plot assumptions.

Plot A1a. Field capacity was 25.5 acre inches per acre.

Depletion rate to 1st irrigation was  $\frac{1}{2}$  July rate.

Plot A2a. Field capacity was 21.0 acre inches per acre.

Plot A3a. Field capacity was 21.9 acre inches per acre.

Plot A4a. Field capacity was 30.0 acre inches per acre.

Pasture: General assumptions

1. Consumptive use began April 17th.
2. The plot was at field capacity on April 17th.
3. The plot was at field capacity 2-4 days after irrigation.
4. The dry weight of core material for each plot was constant.
5. The depletion rate during irrigation period was average of prior and following rate.
6. The extrapolated rate was same as the average alfalfa rate over the same period.
7. The growing season ended November 5th.

Individual field plot assumptions

Plot A1p. Field capacity was 22.0 acre inches per acre.

Plot A2p. Field capacity was 24.0 acre inches per acre.

Plot A3p. Field capacity was 17.5 acre inches per acre.

Ferron Creek Area Assumptions

Small grains and corn: General assumptions

1. Consumptive use began on planting date.
2. The plot was at field capacity on planting date.
3. The plot was at field capacity 2-4 days after irrigation.
4. The dry weight of core material for each plot was constant.
5. The depletion rate during irrigation period was the average of prior and following rate.

6. The depletion rate to 1st irrigation was  $\frac{1}{2}$  June 15 rate.

Individual field plot assumptions

- Plot F1b. Field capacity was 17.8 acre inches per acre.
- Plot F1c. Field capacity was 13.8 acre inches per acre.
- Plot F1w. Field capacity was 17.1 acre inches per acre.
- Plot F2w. Field capacity was 12.5 acre inches per acre.
- Plot F3w. Field capacity was 19.2 acre inches per acre.

Alfalfa: General assumptions

1. Consumptive use began on April 12th.
2. The plot was at field capacity on April 12th.
3. The plot was at field capacity 2-4 days after irrigation.
4. The dry weight of core material for each plot was constant.
5. The depletion rate during irrigation period was the average of prior and following rate.
6. The depletion rate to the 1st irrigation was  $\frac{1}{2}$  June 15 rate.
7. The growing season ended November 5th.

Individual field plot assumptions

- Plot F1e. Field capacity was 25.0 acre inches per acre.
- Plot F2a. Field capacity was 23.0 acre inches per acre.
- Plot F3a. Field capacity was 20.0 acre inches per acre.

Pasture: General assumptions

The same assumptions were used as for alfalfa in the Ferron Creek Area.

Individual field plot assumptions

- Plot F1p. Upper 3 feet of core material was used.
- Field capacity was 12.0 acre inches per acre.
- The depletion rate prior to 1st irrigation was  $\frac{1}{2}$  June 15 rate.

### Discussion

Interviews with the farmers disclosed that the general practice is to irrigate small grains immediately prior to or following the planting date. The volume of irrigation water applied, plus the spring runoff, was considered sufficient to bring the soil to near field capacity. The moisture content at field capacity for each plot was estimated from the soil moisture depletion rates.

The moisture depletion rate, over the early period, was estimated from data obtained on field plots where samples were taken prior to the 1st irrigation. For small grains the average depletion rate, on these plots over the early period, was approximately  $\frac{1}{2}$  the June 15th rate. To verify this average depletion rate, evaporation rates were investigated. The ratio of consumptive use to evaporation from a weather bureau pan was near 0.50 for the small grain plots, over the months of April, May and June. From studies on the Pecos River (2), the ratio of evaporation from bare soil to evaporation from a weather bureau pan, over the same months (April, May and June), was 0.35. For small grains, the additional loss of moisture due to transpiration would increase this ratio of 0.35, and would more nearly approach the value of 0.50. This criterion ( $\frac{1}{2}$  the June 15th rate) was used for the extrapolation of the consumptive use curves as indicated on pages 16 to 19. Similar methods of reasoning are applicable to the assumptions used for the alfalfa and pasture plots.

The unit consumptive use values obtained, and as given in tables 1 and 2, are estimates. Actual field data do not cover the early growing season, however, it was believed a better policy to estimate this early consumptive use than to neglect it entirely.

## Evapo-transpiration Studies

### Installation

Evapo-transpiration, or tank, studies were conducted throughout the growing season of 1949 in the Ashley Valley. Evapo-transpiration studies were not conducted in the Ferron Creek Area. Six tanks had been installed near the Vernal Weather Station, by the Irrigation Division of the Soil Conservation Service, in the spring of 1948. These tanks contained two specimens each of alfalfa, pasture, and wheat. Figure 3 shows the installation. Each tank consists of a perforated inner cylinder, filled with an undisturbed soil core, and placed inside an outer watertight tank. The tops of the tanks are level with the ground surface. The dimensions of the tanks are given in Table 2.

### Operation

The tank studies were late getting started. The wheat tanks had been transplanted by May 31, 1949, at which time the wheat sprouts were approximately two inches high. The alfalfa and pasture tanks had been previously established and reseeding in these tanks was not necessary. The soil columns in the six tanks were filled with water and allowed to stabilize for 24 hours. The elevation of the water in the tanks, after the soil core was saturated, became the reference point. All water added or withdrawn, thereafter, was measured. The water was pumped out and the depth, of water in the bottom of each tank, was maintained at approximately 3" throughout the season with the exception of the alfalfa tanks. From the 1st of August to the end of the growing season, the water in the alfalfa tanks was pumped as low as possible. It was believed that the water in the bottom was giving rise to a water table effect which was inhibiting the plant growth. This was exemplified by the small yield of the 2nd

cutting. The tanks were again filled with water and brought to the reference point at the end of the growing season. The season ended August 16th for the wheat tanks and November 5th for the alfalfa and pasture tanks.

### Summary

The evapo-transpiration experiments are summarized in Table 3.

Table 3. Summary of evapo-transpiration data at Vernal, Utah for 1949.

Tank Crop	Growing Period	Av. Depth to Water	Precip. in Inches	Consumptive Use Plus Precipitation	Yield	Area of Soil Surface in Sq. Feet
Wheat	5/31-8/16	58"	2.5	75.8	53 Bu/ac.	3.0
Wheat <sup>1/</sup>	5/31-8/16	58"	2.5	16.3	65 Bu/ac.	3.0
Pasture	5/31-11/5	46"	7.2	33.6	1.3 T/ac.	6.3
Pasture	5/31-11/5	46"	7.3	35.4	2.4 T/ac.	6.3
Alfalfa	5/31-11/5	46"	5.3	29.3	3.4 T/ac.	6.3
Alfalfa	5/31-11/5	46"	5.3	30.4	4.2 T/ac.	6.3

<sup>1/</sup> Data questionable due to hole in tank approximately 2' below surface.

### Comparison of Unit Consumptive Use Data

The results of unit consumptive use for the major crops compare favorably by both methods (soil moisture depletion and evapo-transpiration) in the Ashley Valley (table 4). Pasture shows a higher consumptive use than alfalfa, which appears reasonable under the existing water table conditions. The consumptive use by alfalfa of 28.3 acre inches per acre, determined by the tank studies, was low as compared to 32.5 acre inches per acre determined by the soil moisture depletion studies. The unit consumptive use for wheat of 21.5 acre inches per acre by the tank experiments check, within 5 percent, the value of 20.4 acre inches per

acre determined by the soil moisture depletion studies. In the Ferron Creek Area, the following unit consumptive use values were determined by soil moisture depletion studies; 31.2 acre inches per acre by alfalfa, 30.1 acre inches per acre by pasture, and 19.0 acre inches per acre by small grains. These consumptive use values obtained for the 1949 growing season, in both the Ashley and Ferron Creek Areas, are higher than those reported by Criddle and Peterson (6), for the 1948 growing season (see page 10).

Table 4. Summary of Average Unit Consumptive Use Values and Yield Data

Item	Unit Consumptive Use (inches)			Yield Data <sup>2/</sup>		
	Alfalfa	Pasture	Small Grains (wheat)	Alfalfa	Pasture	Small Grains (wheat)
Tank Plots <sup>1/</sup>	28.3	32.0	21.5	3.8 T/acre	1.9T/acre	59.0 Bu/acre
Ashley Valley	32.5	33.3	20.4	5.1 T/acre	---	49.0 Bu/acre
Ferron Valley	31.2	30.1	19.0	5.1 T/acre	---	49.2 Bu/acre

<sup>1/</sup> Extrapolated consumptive use values (see table 9 for extrapolated period).

<sup>2/</sup> Average yield values.

6.1 6.4 7.4



FIGURE 1  
Typical corn plot in Ashley Valley.



FIGURE 2  
Standard automatic rain gage.



FIGURE 3  
Evapo-transpiration installation.

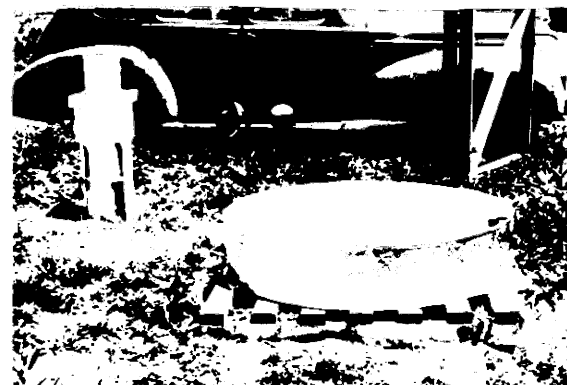


FIGURE 4  
Standard evaporation pan, anemometer,  
and rain gage.



FIGURE 5  
Field sampling equipment.

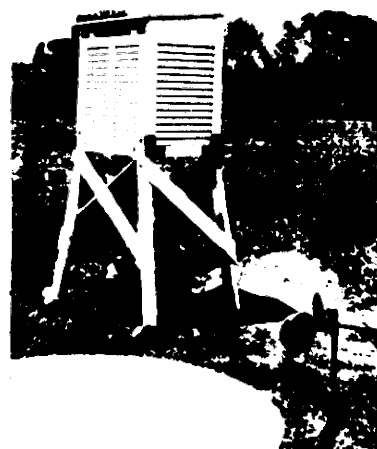


FIGURE 6  
Weather station house.

## APPLICATION OF EXPERIMENTAL DATA

Several methods have been proposed to apply experimental data to regions with environments different from those under which the tests were conducted. Since consumptive use is highly dependent upon several factors, allowances must be made for the differences encountered in the areas with these different environments.

A Method of Application

Available moisture and available heat are perhaps the two most important factors which influence the consumptive use. Blaney and Criddle (1) have developed a method for extending experimental data based on mean temperature and percent of daytime hours. By multiplying the mean monthly temperature ( $t$ ) by the monthly percent of daytime hours of the year ( $p$ ), there is obtained a monthly consumptive use factor ( $f$ ). It is then assumed that the consumptive use varies directly as this factor or, expressed mathematically,

$$U = KF$$

where:  $U$  = Consumptive use of crop in inches for any period.

$F$  = Sum of the monthly consumptive use factors for the period. (Sum of the products of mean monthly temperature and monthly percent of annual daylight hours), or ( $t \times p$ ):

$K$  = An empirical coefficient.

$t$  = Mean monthly temperature in degrees Fahrenheit.

$p$  = Monthly percent daytime hours of the year.

$f = t \times p$  = Monthly consumptive use factor.

The assumptions involved in the formula  $U = KF$ , limit the scope and



Table 5

Calculated monthly consumptive use factors, Vernal, Utah 1949. Latitude = 40° 30'N.

Month	% Daytime hours $\frac{1}{p}$ (p)	Mean Temperature (t)	Consumptive Use Factor (f)	Accumulative Con. Use Factor (F)
April	8.96	49.0	4.40	4.40
May	10.05	53.0	5.35	9.75
June	10.11	60.6	6.15	15.90
July	10.25	68.5	7.04	22.94
Aug.	9.56	67.3	6.45	29.39
Sept.	8.39	59.2	4.98	34.37
Oct.	7.74	50.8	3.94	38.31
Nov.	6.69	33.4	2.24	40.55

 $\frac{1}{p}$  From Table 16

Table 6

Calculated monthly consumptive use factors, Ferron, Utah 1949. Latitude = 39° 00'N.

Month	% Daytime hours $\frac{1}{p}$ (p)	Mean Temperature (t)	Consumptive Use Factor (f)	Accumulative Con. Use Factor (F)
April	8.93	49.9	4.46	4.46
May	9.97	54.7	5.45	9.91
June	10.02	62.1	6.25	16.16
July	10.16	71.0	7.25	23.38
Aug.	9.51	70.7	6.74	30.12
Sept.	8.38	64.1	5.39	35.51
Oct.	7.77	47.1	3.67	39.18
Nov.	6.77	43.4	2.94	42.12

 $\frac{1}{p}$  From Table 16

**Table 7**  
Determination of empirical coefficient for major crops in Ashley Valley, 1949.

Crop	Field Plot Designation	Growing Period	Consumptive Use Data			
			U	F	K	Avg. K
Alfalfa	Average	4/17-11/5	32.5	36.2	.90	.90
Pasture	Average	4/17-11/5	33.3	36.2	.92	.92
Barley	Alb	4/15-8/26	17.8	26.1	.68	
	A2b	4/20-8/16	20.3	23.3	.87	
Oats	Alc	4/15-9/7	17.6	28.4	.62	
	A2c	4/25-10/1	20.8	30.9	.67	
	A3c	4/25-9/7	21.0	27.0	.78	
Wheat	Alw	4/10-9/7	16.3	29.1	.56	
	A2w	4/15-9/7	24.4	28.4	.86	
Corn	Alc	5/24-9/20	20.8	24.2	.86	
	A2c	5/5 -10/1	23.6	29.1	.81	
	A3c	5/25-10/8	18.9	26.7	.71	.74

**Table 8**  
Determination of empirical coefficient for major crops in Ferron Valley, 1949.

Crop	Field Plot Designation	Growing Period	Consumptive Use Data			
			U	F	K	Avg. K
Alfalfa	Average	4/12-11/5	31.2	37.9	.82	.82
Pasture	Average	4/12-11/5	30.1	37.9	.79	.79
Barley	F1b	4/25-9/12	19.2	28.6	.67	
Corn	F1c	5/15-9/22	18.8	27.0	.70	
Wheat	F1w	4/15-9/12	18.1	30.0	.61	
	F2w	4/25-9/12	19.4	28.6	.68	
	F3w	4/25-9/12	19.5	28.6	.68	.67

**Table 9**  
Determination of empirical coefficient for evapo-transpiration tanks in  
Ashley Valley 1949..

Crop	Field Plot Designation	Growing Period <sup>1/</sup>	Consumptive Use Data			
			U	F	K	Avg. K
Alfalfa	Average	4/17-11/5	28.3	36.2	.78	.78
Pasture	Average	4/17-11/5	32.0	36.2	.88	.88
Wheat	Average	4/20-8/16	21.5	23.3	.91	.91

<sup>1/</sup> Includes extrapolated period.

accuracy of the method. Probably this method should be used to determine preliminary estimates of consumptive use in areas where more exact methods are unwarranted.

#### Comparison with Recommended Coefficients

Tables 7 and 9 respectively, show the values determined for the empirical coefficients for the major crops in the Ashley Valley by soil moisture depletion and evapo-transpiration studies. Tables 5 and 6 show the calculations of the monthly use factors ( $f$ ). The average value of the empirical coefficient for alfalfa ( $K = 0.86$ ) checks within reasonable limits the value as given by Blaney and Criddle ( $K = 0.85$ ) (1). The average result for small grains ( $K = 0.86$ ) and for pasture ( $K = 0.90$ ) show somewhat higher values than those given by Blaney and Criddle ( $K = 0.75$ ) for both pasture and grain. In the Ferron Creek Area, for alfalfa  $K$  is 0.82, for pasture  $K$  is 0.79, and for small grains  $K$  is 0.67 (table 8). It should be noted that the alfalfa and pasture plots were computed for the entire growing season and not the frost free period.

## YIELD DATA

Yield data for the various crops were obtained to supplement the consumptive use data at the request of one of the cooperating agencies.

### Field Procedure

The yield samples were taken on alfalfa and small grain plots. A one-quarter inch diameter steel rod was bent into a U-shape such that the bends were sharp and at 90 degrees. All sides of the U-shape were three feet long, thus the U-shape covered an area of 9 square feet. The fourth side was closed by means of a steel tape which was aligned after the U-shape was in place. Four samples were taken on each field in the vicinity of the established soil moisture sampling plot. The samples were selected at random within this vicinity. The procedure was to take the samples at a distance of 10 steps from the established soil sampling plot. One sample was taken in each of the four general directions from the plot.

### Discussion

No yield samples were obtained by the above procedures on the 1st cutting of alfalfa. Comparisons of the 1st and 2nd cutting of alfalfa were obtained on farms where the alfalfa was baled. Five bales picked at random from 1st and 2nd cuttings were weighed and a yield ratio established. This yield ratio was used in estimating the yield of the 1st cutting on other farms. Table 4 indicates the average yield obtained for alfalfa and wheat as compared with the average consumptive use. There appears to be a definite trend of use versus yield, however data are insufficient to be conclusive.

## SUMMARY

1. Consumptive use of water will serve as a basis for administration of the provisions of the Upper Colorado River Compact. Thus, information regarding consumptive use by the major crops is urgently needed for the Colorado River Area of Utah.
2. Consumptive use of water is a variable quantity. Temperature, available moisture supply, and irrigation practices are the factors which probably exert the most influence on the volume of water actually consumed by plants. In extending unit consumptive use values from one area to another, corrections must be made to account for differences in these factors in the areas concerned.
3. The methods used to determine consumptive use of water are the inflow-outflow and the integration methods. Unit consumptive use values are required to obtain the total consumptive use by the integration method. Soil moisture depletion and evapo-transpiration studies are the usual methods of determining unit consumptive use values.
4. Soil moisture depletion studies in the Ashley and Ferron Creek Areas for 1949 show somewhat higher unit consumptive use values than obtained during the 1948 season (6). This variation resulted from the added increment of use over the early growing period for the 1949 season. Also, there was more precipitation during the 1949 growing season as shown by tables 14 and 15. This added precipitation stimulated more active plant growth on the plots studied, which in turn, increased the consumptive use.
5. The unit consumptive use values as determined by the soil moisture depletion studies are in close agreement with the values obtained from the evapo-transpiration tank experiments. Table 4 indicates the average of the computed values.

6. Data obtained from the soil moisture depletion studies indicate that improved methods of taking soil samples are needed. Large variations occurred in total dry weights for a given increment of depth for an established plot. This discrepancy resulted in wide ranges of apparent specific gravity, which in turn directly affected the computed volume of water in the soil. Further studies of this type should be based on definitely established dry weight and apparent specific gravity data for each plot.

7. Field sampling should cover the actual growing season rather than the frost free period. Considerable volumes of water may be consumptively used prior to the last killing frost in the spring and after the first killing frost in the fall. Farmers testimonies and field observations made in this study indicate that alfalfa and native vegetation which is still moist will withstand heavy frosts and continue to grow.

8. From this study, it would appear that empirical expressions for transferring consumptive use data from one area to another are justified only where more exact methods are not warranted.

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## APPENDIX A

Climatological Data and Maps of the Areas.



Table 10. SUMMARY OF CLIMATOLOGICAL DATA IN ASHLEY VALLEY, UTAH, 1949.

Week Ending	Precipitation in inches $\frac{1}{2}$	Evaporation in inches	Temperature of	Wind in miles	Humidity	
					Max.	Min.
Apr. 2	-					
9	.05		47		99	48
16	-		47		99	36
23	-		53		99	44
30	.04		48		99	47
May 7	.25	1.91	51		96	55
14	.14	1.57	53		98	52
21	.61	1.13	52		100	60
28	-	1.61	56		96	45
June 4	-	1.22	53		99	60
11	.43	1.82	63		98	67
18	.65	2.26	64		98	55
25	.09	1.86	62		95	43
July 2	.36	1.98	63	231.9	99	48
9	.27	1.41	65	188.5	99	58
16	.07	1.64	70	201.5	94	42
23	.08	1.81	69	222.4	99	46
30	.04	1.78	69	168.2	99	45
Aug. 6	-	1.99	72	116.9	98	48
13	.01	1.37	67	181.3	99	37
20	-	1.27	64	133.1	100	38
27	.15	1.86	67	187.6	100	49
Sept 3	-	1.18	64	194.8	96	42
10	.14	1.33	60	237.9	98	44
17	-	1.55	56	239.9	100	42
24	-	1.32	57	188.1	100	34
Oct. 1	.38	.92	59	178.1	100	40
8	1.08	.68	51	268.9	99	62
15	.39	.86	45	228.4	98	74
22	1.94	.54	43	255.2	98	69
29	-	.42	40	133.0	99	65
Nov. 5	-	.37	40	208.5	99	53
12	.31	.32	38	206.8	99	56

 $\frac{1}{2}$  Average of 3 recording stations.

Table 11. SUMMARY OF CLIMATOLOGICAL DATA IN FERRON CREEK AREA, UTAH, 1949

Week Ending	Precipitation in inches	Evaporation in inches	Temperature °F	Wind in miles <sup>1/</sup>	Humidity	
					Max.	Min.
Apr. 2	.48					
9	-				95	42
16	-	1.47	46		86	36
23	-	1.60	46		89	46
30	.07	1.45	54		89	47
May 7	.14	1.32	59		94	53
14	.35	1.55	51		95	48
21	.09	1.06	55		99	51
28	-	1.62	60		91	41
June 4	1.01	1.42	53		96	59
11	.24	1.00	58		99	58
18	-	1.66	68		85	48
25	.43	1.63	64	1165	78	36
July 2	-	1.77	68	859	87	42
9	.20	1.20	68	-	94	51
16	.21	1.50	68	573	90	48
23	-	1.80	72	791	93	49
30	-	1.58	75	620	78	30
Aug. 6	.23	1.20	78	-	94	51
13	.35	1.13	69	619	60	32
20	-	1.45	69	-	86	40
27	.13	1.61	68	-	81	38
Sept 3	-	1.53	70	775	86	41
10	.17	1.13	67	-	83	46
17	.13	1.23	62	-	90	40
24	-	1.40	63	954	67	32
Oct. 1	.16	1.03	62	416	99	50
8	.35	.99	52	-	90	45
15	-	.46	44	-	97	53
22	.28	.29	44	515	99	56
29	-	.45	43	-	96	42
Nov. 5	-	.41	43	438	96	37
12	.14	.71	44	780	100	62

<sup>1/</sup> Operation of anemometer questionable.

Table 12. Average monthly temperature in °F., at Vernal, Utah.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Growing Season <sup>1/</sup>
1937	4.0	12.3	29.4	43.6	58.0	61.0	70.3	68.5	61.2	50.3	40.6	27.2	43.2	61.6
1938	25.0	29.7	35.6	45.8	53.2	65.6	67.6	67.3	61.6	49.1	27.6	23.6	46.0	60.7
1939	16.0	10.4	32.8	-----	-----	60.0	70.6	68.4	60.4	46.4	35.2	28.0	-----	-----
1940	-----	19.6	39.6	47.0	58.3	67.4	71.4	69.8	60.8	48.6	29.6	21.2	-----	62.8
1941	14.0	24.0	37.1	43.3	56.4	61.4	69.2	67.2	55.8	45.2	35.2	25.6	44.6	59.2
1942	14.7	21.5	32.4	46.9	51.8	60.1	68.6	-----	58.2	49.3	32.8	25.0	-----	-----
1943	23.8	28.6	34.2	51.2	52.6	58.0	67.2	-----	-----	-----	36.4	23.4	-----	-----
1944	8.4	14.3	28.6	41.8	54.3	59.6	67.4	65.8	59.6	49.6	33.2	23.6	42.2	59.3
1945	25.4	29.5	34.8	38.8	54.6	55.5	68.8	67.0	64.9	47.2	29.8	17.6	43.7	58.0
1946	17.0	24.6	39.0	53.8	51.2	-----	-----	-----	-----	-----	-----	-----	-----	-----
1947	-----	-----	-----	-----	55.9	57.8	67.6	65.9	59.3	51.0	27.7	16.7	-----	59.5
1948	-----	18.6	29.1	44.3	52.9	61.0	66.9	65.3	59.8	46.4	-----	-----	-----	58.7
1949	-----	-----	-----	49.0	53.0	60.5	67.9	67.0	59.3	44.3	39.2	-----	-----	58.6
Ave.	15.5	21.2	33.9	46.0	54.4	60.6	68.5	67.3	59.2	50.8	33.4	23.2	43.9	59.8

<sup>1/</sup> For purposes of this table, considered from May 1 to October 31 of each year.

Table 13. Average monthly temperature in °F., at Castle Dale, Utah, 1932 to 1942; Ferron, Utah, 1948 & 1949.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Annual	Growing Season <sup>1/</sup>
1932	8.0	25.2	34.2	44.8	52.0	61.5	68.5	65.9	59.0	43.2	32.4	10.5	42.1	59.3
1933	6.5	5.3	34.7	39.2	48.0	64.9	70.0	65.7	61.4	49.8	34.4	26.2	42.2	60.0
1934	26.9	35.3	43.8	49.4	60.0	61.0	72.6	69.3	57.4	48.0	34.4	26.2	48.7	61.5
1935	25.1	30.6	34.0	45.1	50.2	66.0	69.1	67.2	60.6	44.2	30.0	22.8	45.4	59.5
1936	19.6	29.2	37.8	47.7	56.7	66.7	69.0	68.4	57.2	45.9	30.8	23.2	46.0	60.5
1937	2.4	13.8	33.2	42.5	57.4	62.2	69.0	68.0	59.5	46.8	34.6	28.0	42.7	60.5
1938	23.1	29.6	34.6	45.0	51.2	65.0	67.4	68.2	59.9	47.6	25.9	24.7	45.2	59.8
1939	18.0	7.4	-----	47.4	-----	60.4	71.0	69.0	61.3	48.7	39.9	30.0	-----	-----
1940	21.8	33.0	42.2	49.0	60.6	69.7	72.2	70.8	63.0	51.8	-----	-----	-----	64.7
1941	-----	-----	41.8	43.7	58.4	62.9	70.8	68.8	56.8	47.0	37.0	30.8	-----	60.8
1942	22.7	24.8	36.7	47.6	-----	65.2	73.8	69.2	59.1	52.0	37.3	31.2	-----	-----
Ave.	16.9	23.4	37.3	45.6	55.0	64.1	70.3	68.3	59.6	47.7	33.7	25.4	45.6	60.8
<u>FERRON</u>														
1948	-----	-----	-----	46.2	56.4	64.0	70.8	68.4	64.4	49.8	-----	-----	-----	62.3
1949	13.3	16.5	36.3	49.9	54.7	62.1	71.0	70.7	64.1	47.1	43.4	-----	-----	61.6

<sup>1/</sup> For purposes of this table, considered from May 1 to October 31 of each year.

Table 14. Monthly precipitation, in inches, at Vernal, Utah.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Growing Season <sup>1/</sup>
1927	0.40	2.20	0.46	0.42	1.17	0.24	1.57	1.15	0.47	0.25	0.00	0.90	9.43	4.65
1928	T	0.65	2.33	0.41	2.44	0.77	0.28	0.00	2.38	1.93	1.49	0.65	13.46	7.75
1929	0.51	1.19	0.50	0.28	0.40	0.40	1.47	0.43	2.99	1.51	0.00	0.12	9.15	6.25
1930	1.08	0.95	0.77	1.23	0.03	0.00	0.10	0.34	1.65	0.38	0.50	0.73	8.46	2.70
1931	0.69	0.30	0.60	1.76	0.70	1.22	0.23	2.07	2.60	3.07	0.55	0.67	14.73	9.77
1932	T	0.27	0.75	1.39	0.56	0.00	0.65	0.32	0.33	0.30	T	0.51	5.81	2.71
1933	0.73	0.68	0.66	0.77	0.26	0.19	0.90	3.24	1.76	2.00	0.53	1.14	17.01	5.35
1934	1.33	0.62	1.00	1.31	0.49	1.31	0.00	0.00	0.42	0.50	1.00	T	8.91	2.65
1935	0.43	0.64	0.84	0.31	0.97	1.90	0.64	1.17	0.18	1.00	0.25	0.68	8.86	5.46
1936	0.11	0.02	0.46	1.34	0.40	---	0.00	---	---	---	---	---	---	---
1937	---	---	---	---	0.86	2.92	0.13	2.19	0.29	1.17	0.33	0.79	---	7.61
1938	---	0.59	0.45	0.23	0.45	1.14	1.19	0.66	0.46	0.59	---	---	---	4.49
1939	---	---	---	---	1.00	1.33	0.46	0.16	0.52	3.41	---	---	---	7.08
Ave.	1.12	0.76	0.43	0.95	0.75	1.02	0.51	0.98	1.22	1.29	0.50	0.62	10.74	5.69

<sup>1/</sup> For purposes of this table, considered from May 1 to October 31 of each year.

Table 15. Monthly precipitation, in inches, at Castle Dale, Utah,  
1932 to 1942; Ferron, Utah, 1948 and 1949.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Growing Season <sup>1/</sup>
1932	0.42	1.00	0.06	0.26	0.08	0.66	2.18	2.58	0.25	0.20	0.00	0.96	8.65	5.95
1933	1.60	0.15	0.40	T	0.88	0.00	2.27	0.37	1.26	0.32	0.85	0.58	8.68	5.10
1934	0.38	0.30	T	0.18	0.54	0.01	0.53	0.41	0.15	T	0.23	0.56	3.29	1.64
1935	0.33	0.66	1.07	1.41	0.73	0.00	0.88	0.52	T	0.00	0.11	0.48	6.19	2.13
1936	0.42	0.68	0.92	0.02	0.68	0.62	3.21	0.64	0.55	0.85	0.05	1.65	10.29	6.55
1937	1.12	0.61	0.90	0.04	0.97	0.50	2.04	1.61	0.91	0.46	0.08	0.70	9.94	6.49
1938	0.65	0.44	1.02	0.16	0.72	0.83	0.52	0.88	1.84	1.14	T	0.15	8.35	5.93
1939	1.44	0.84	0.50	0.50	0.58	T	T	1.07	2.24	0.47	0.40	0.12	8.16	4.36
1940	0.75	0.70	0.07	0.10	T	1.08	0.37	T	2.11	1.00	0.90	0.75	7.83	4.56
1941	1.13	0.96	1.30	1.86	2.73	1.10	0.44	1.95	0.73	3.65	0.30	0.90	17.05	10.60
1942	0.08	0.08	0.21	0.83	0.02	0.00	0.09	0.15	0.77	1.58	0.15	0.00	3.97	2.62
Ave.	0.76	0.58	0.59	0.48	0.72	0.44	1.14	0.93	0.97	0.88	0.28	0.62	8.20	5.09
<u>FERRON</u>														
1948	—	—	—	0.06	0.27	0.99	0.15	0.53	0.39	1.71	—	—	—	3.04
1949	2.65	0.41	0.50	0.55	0.53	1.68	0.41	0.71	0.46	0.63	0.14	1.39	5.64	4.47

<sup>1/</sup> For purposes of this table, considered from May 1 to October 31 of each year.

Table 16. Daytime hours in mean solar time, (sunrise to sunset) with percentages for each month of the year for Latitude 37 to 42 degrees north of the equator<sup>1/</sup>

Month	Latitude in degrees north of the equator											
	37		38		39		40		41		42	
	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent
January	308.4	6.93	305.9	6.87	303.4	6.81	300.9	6.76	298.2	6.69	295.3	6.62
February	303.5	6.82	302.2	6.79	300.9	6.76	299.7	6.73	298.2	6.69	296.6	6.65
March	371.4	8.35	371.2	8.34	371.1	8.33	371.0	8.33	370.8	8.32	370.6	8.31
April	394.8	8.87	396.1	8.90	397.4	8.93	398.6	8.95	399.9	8.98	401.1	9.00
May	439.0	9.87	441.4	9.92	444.0	9.97	446.2	10.02	449.0	10.08	451.8	10.14
June	440.1	9.89	443.0	9.95	445.0	10.02	448.9	10.08	452.0	10.14	455.1	10.21
July	447.1	10.06	449.8	10.10	452.6	10.16	455.2	10.22	458.3	10.29	461.4	10.35
August	420.0	9.44	421.7	9.47	423.5	9.51	425.1	9.54	426.9	9.58	428.7	9.62
September	372.4	8.37	372.9	8.38	373.1	8.38	373.5	8.38	374.0	8.39	374.3	8.40
October	348.1	7.82	347.3	7.80	346.1	7.77	345.2	7.75	344.1	7.72	343.1	7.70
November	305.6	6.87	303.7	6.82	301.5	6.77	299.4	6.72	297.0	6.67	294.9	6.62
December	299.2	6.72	296.3	6.66	293.4	6.59	290.6	6.52	287.3	6.45	284.5	6.38
Total	4449.6	100.00	4451.5	100.00	4453.0	100.00	4454.3	100.00	4455.7	100.00	4457.4	100.00

<sup>1/</sup> From "Sunshine Tables", U. S. Weather Bureau Bulletin No. 805, Edition of 1905.





# LEGEND OF FIELD PLOTS

F - Ferron Creek Area  
a - Alfalfa  
b - Barley  
c - Corn  
p - Pasture  
w - Wheat  
1,2,3 - Plot Number

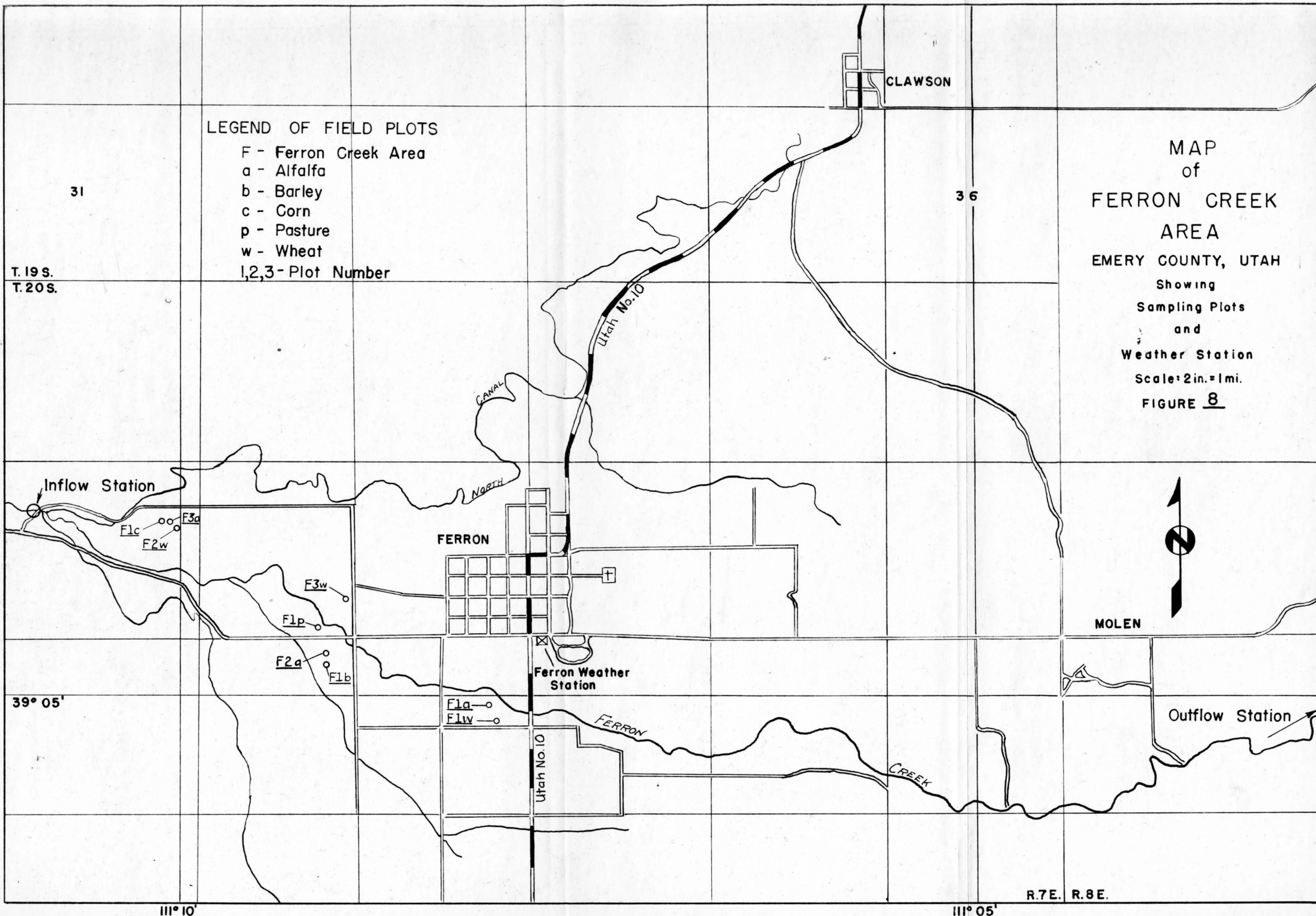
## MAP of FERRON CREEK AREA

EMERY COUNTY, UTAH

Showing  
Sampling Plots  
and  
Weather Station

Scale: 2 in. = 1 mi.

FIGURE 8



## APPENDIX B

### Soil Moisture Depletion Rates and Accumulative Consumptive Use Curves

Assumptions used in extrapolation of curves are given on pages 16 to 19.

#### Legend:

Extrapolated period is shown by broken lines.

Soil moisture depletion is shown by series of short straight lines.

Accumulated consumptive use of water is shown by heavy smooth curves.

Extrapolated soil moisture content is shown by closed circles.

Measured soil moisture content is shown by open circles.

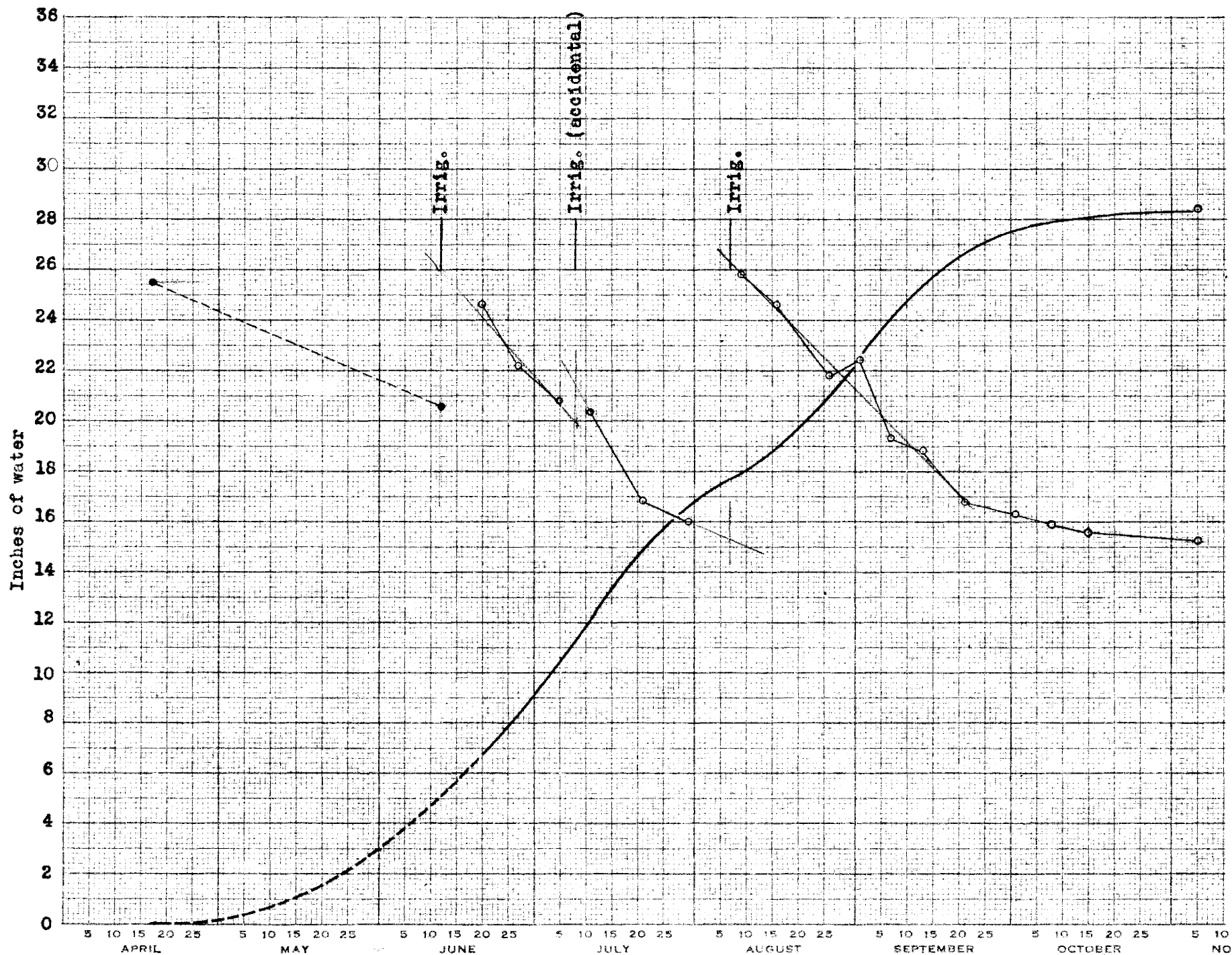


Figure 9 Plot Ala. Consumptive use of water by alfalfa, 1949, Ashley Valley, Utah.

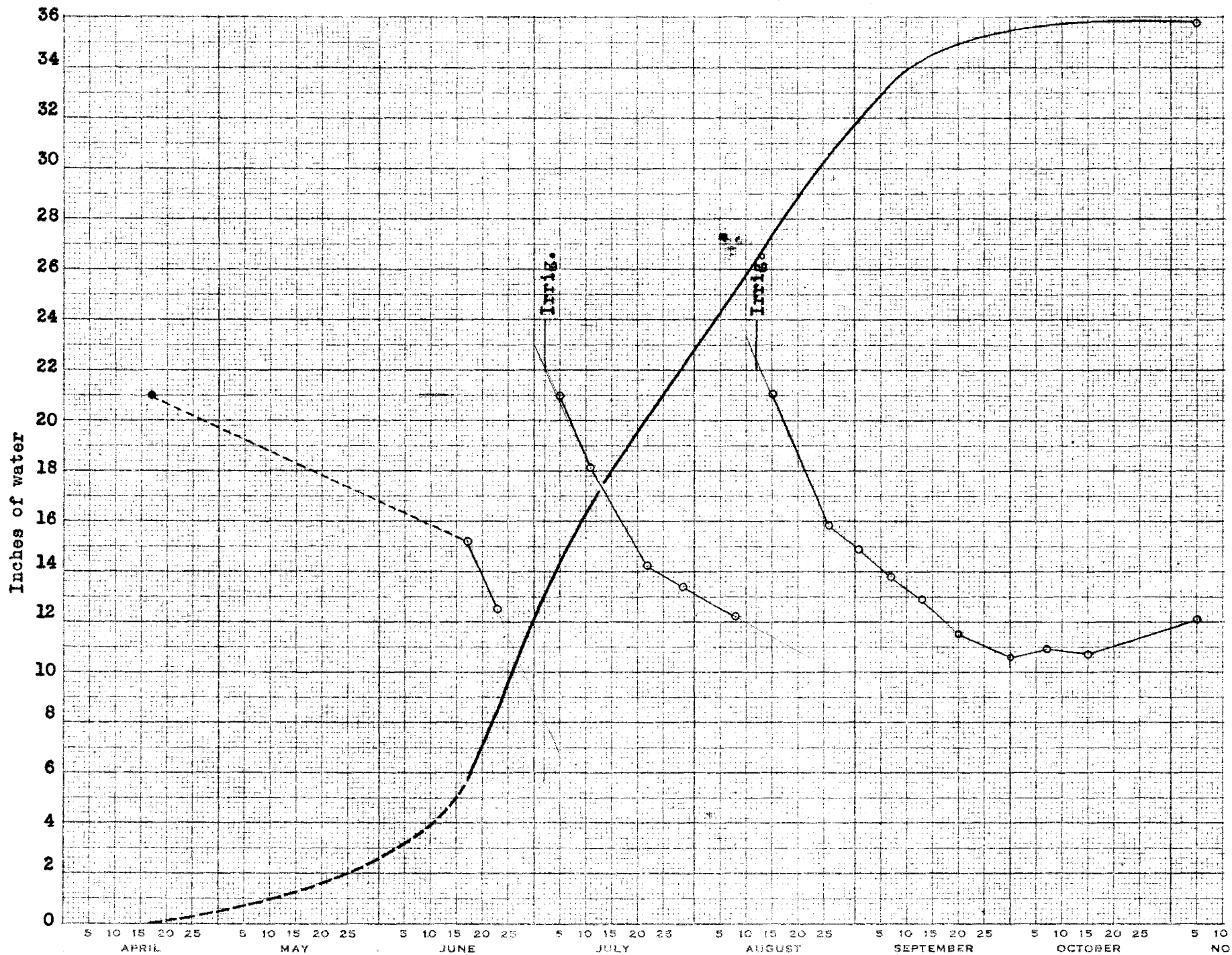


Figure 10 Plot A2a. Consumptive use of water by alfalfa, 1949, Ashley Valley, Utah.

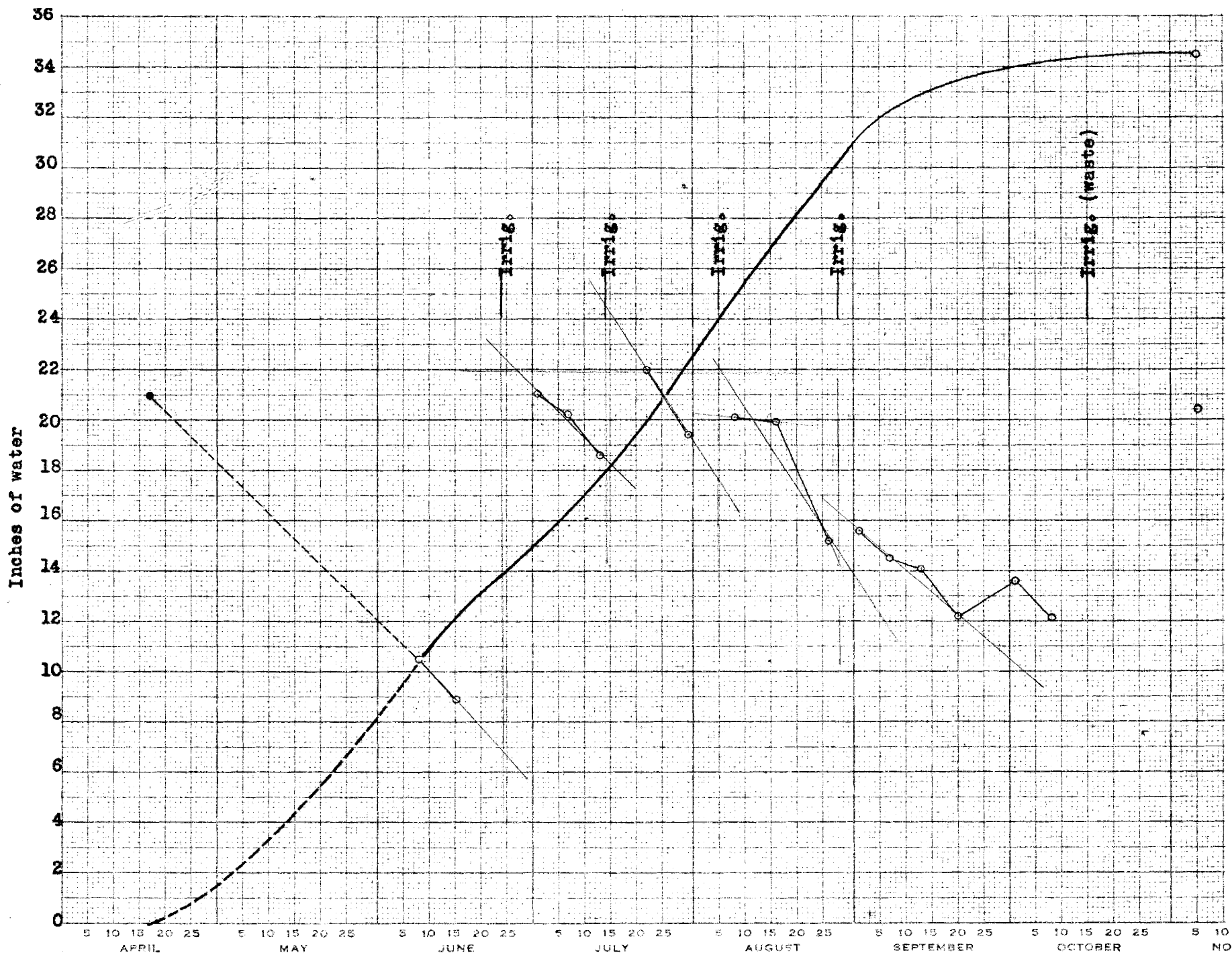


Figure 11 Plot A3a. Consumptive use of water by alfalfa, 1949, Ashley Valley, Utah.



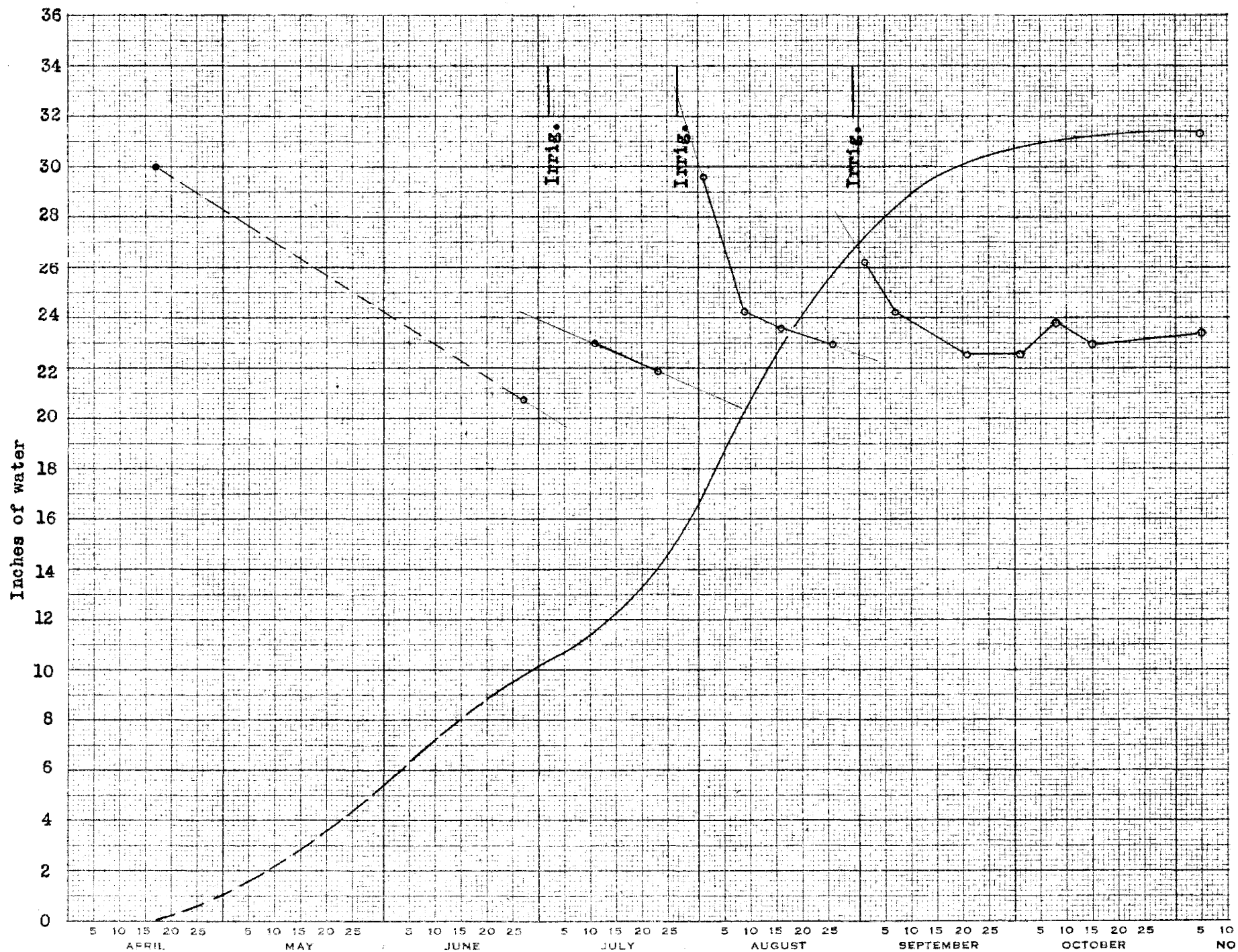


Figure 12 Plot A4a. Consumptive use of water by alfalfa, 1949, Ashley Valley, Utah.

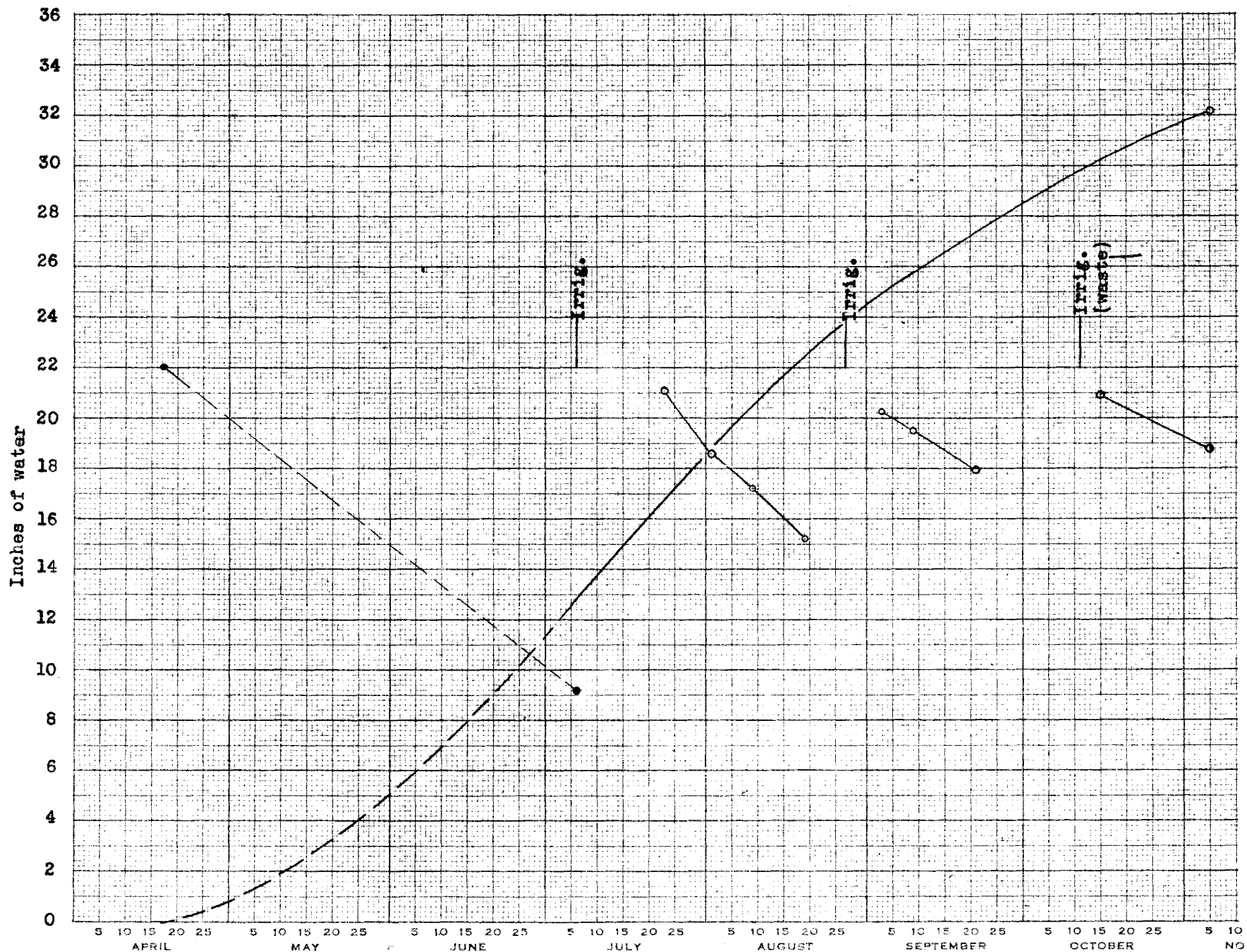


Figure 13 Plot Alp. Consumptive use of water by pasture, 1949, Ashley Valley, Utah.

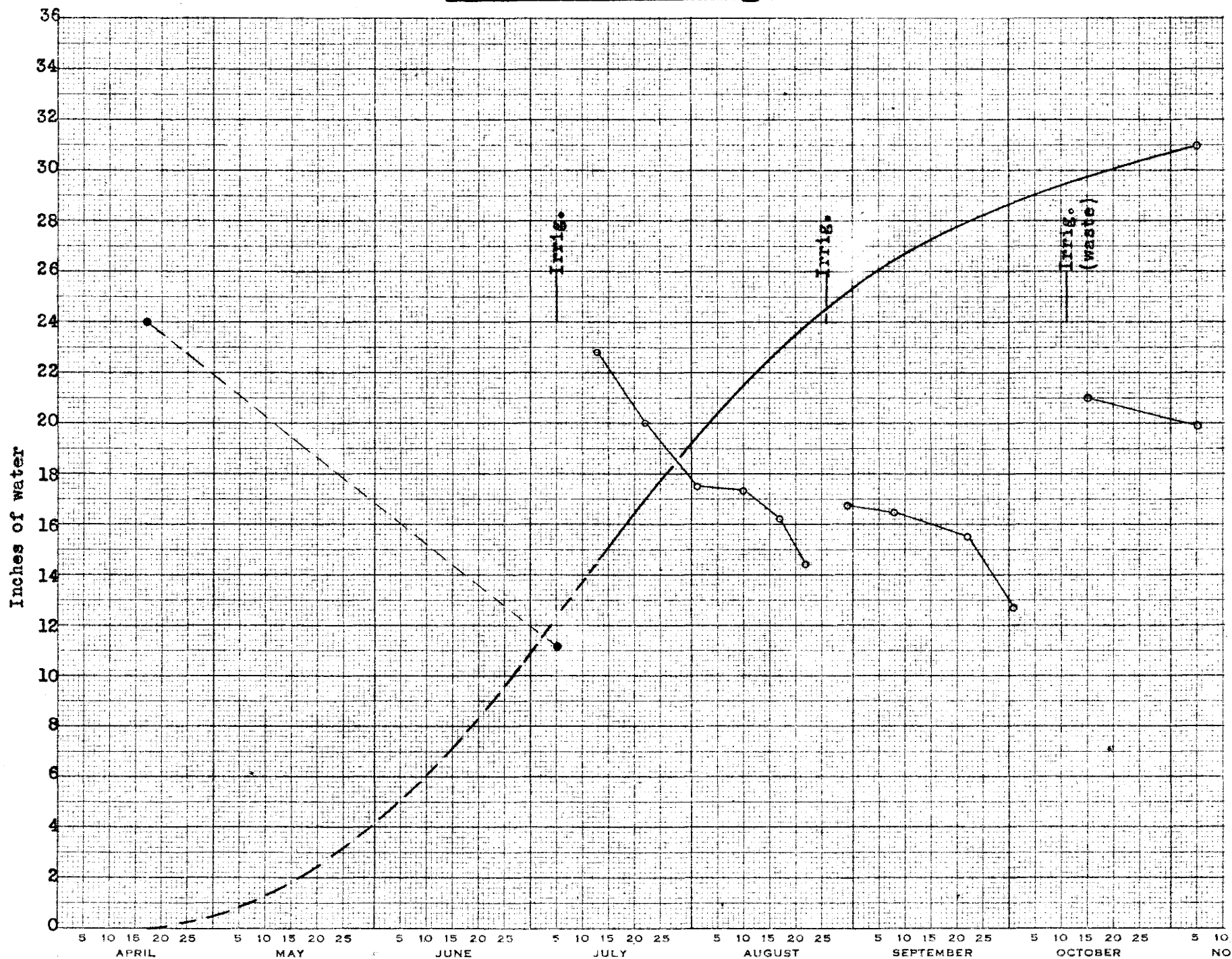


Figure 14 Plot A2p. Consumptive use of water by pasture, 1949, Ashley Valley, Utah.



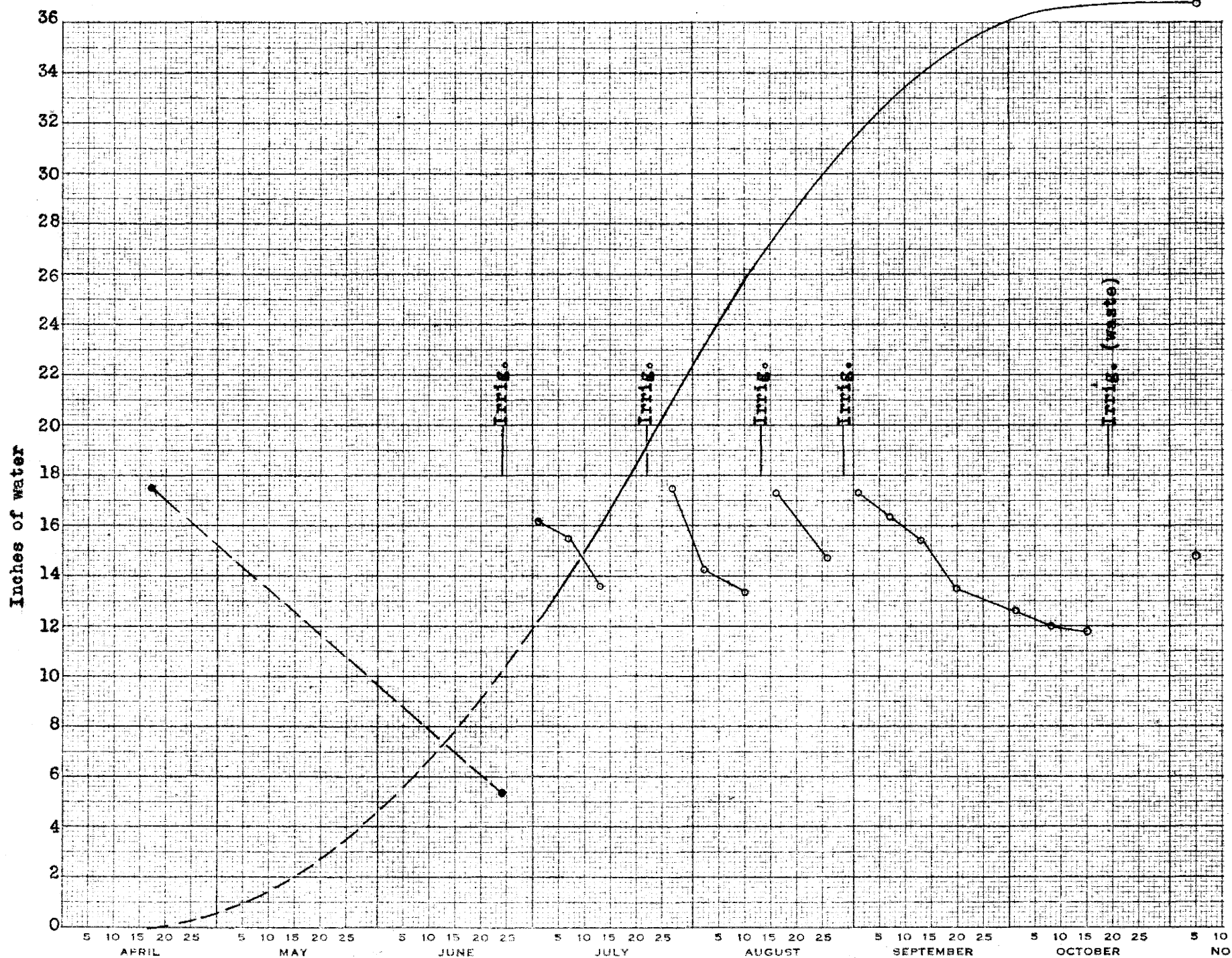


Figure 15 Plot A3p. Consumptive use of water by pasture, 1949, Ashley Valley, Utah.

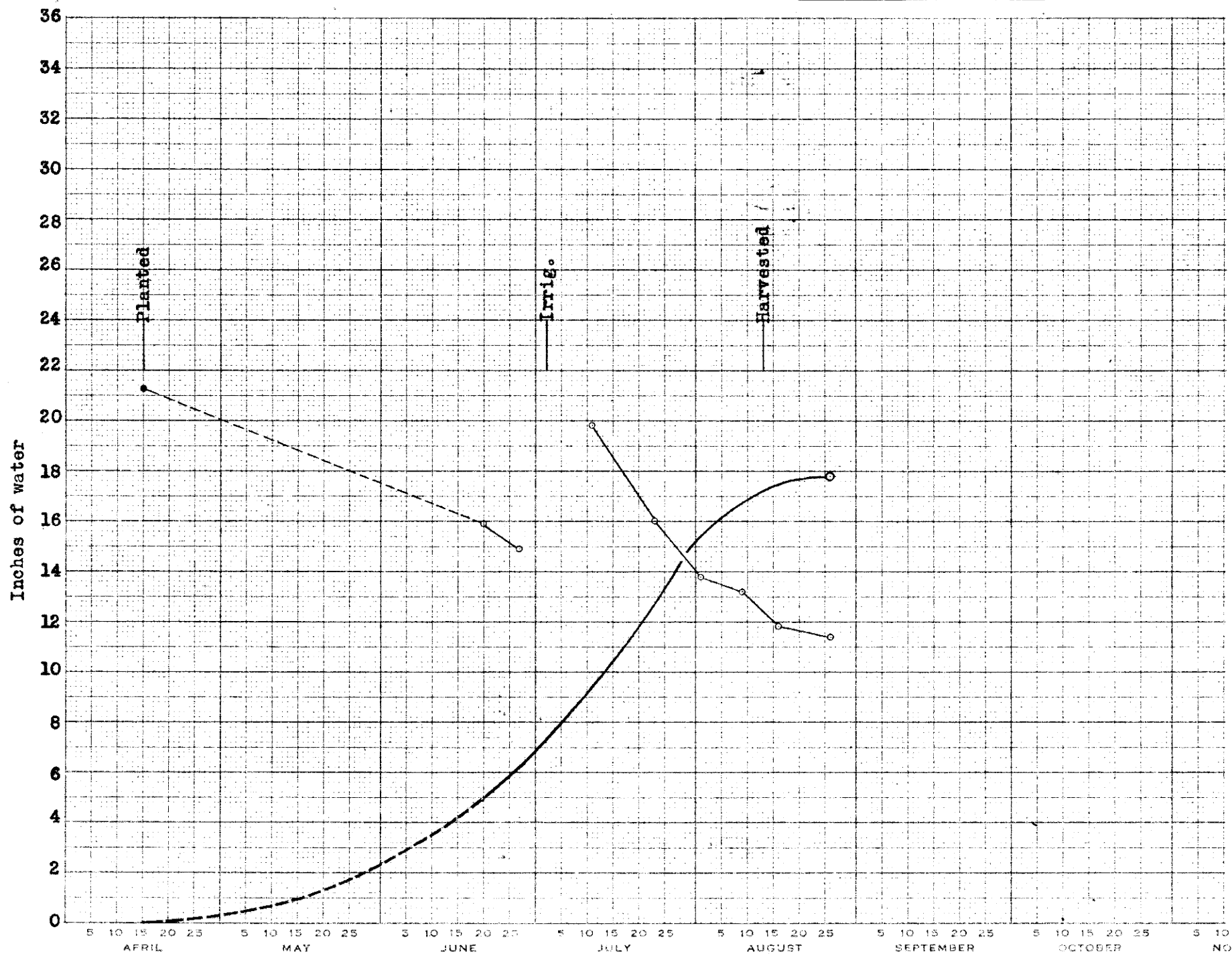


Figure 16 Plot Alb. Consumptive use of water by barley, 1949, Ashley Valley, Utah.

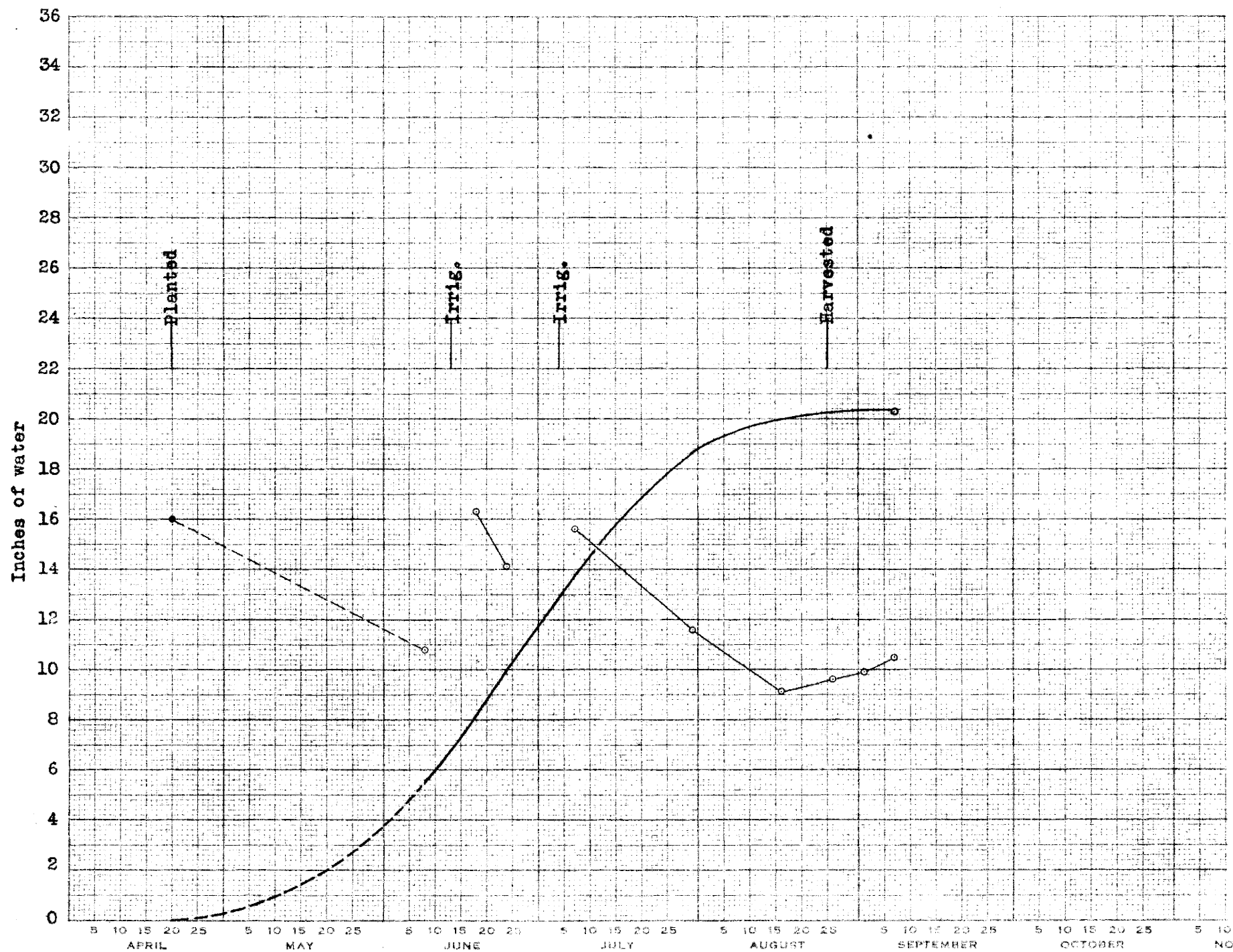


Figure 17 Plot A2b. Consumptive use of water by barley, 1949, Ashley Valley, Utah.

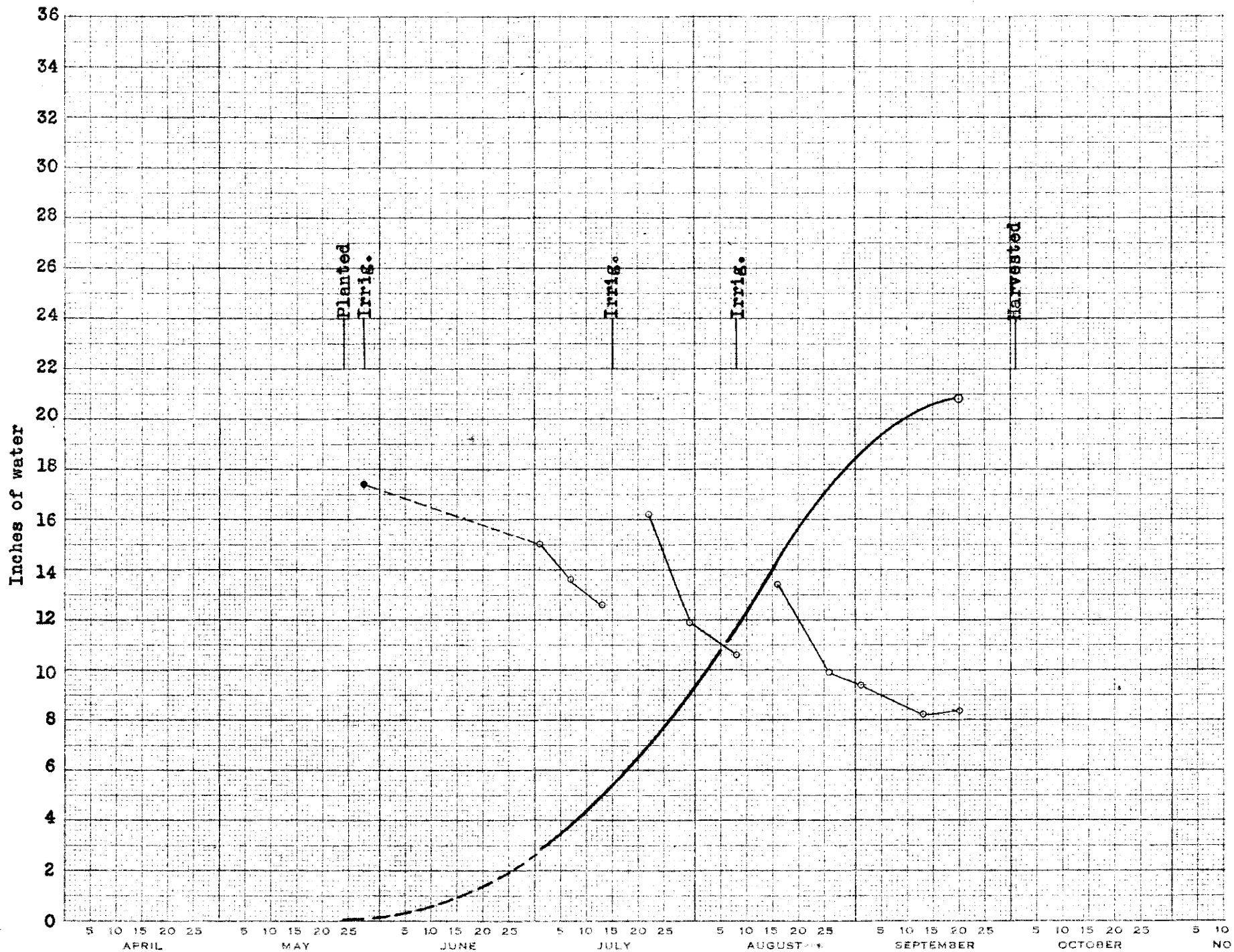


Figure 18 Plot Alc. Consumptive use of water by corn, 1949, Ashley Valley, Utah.

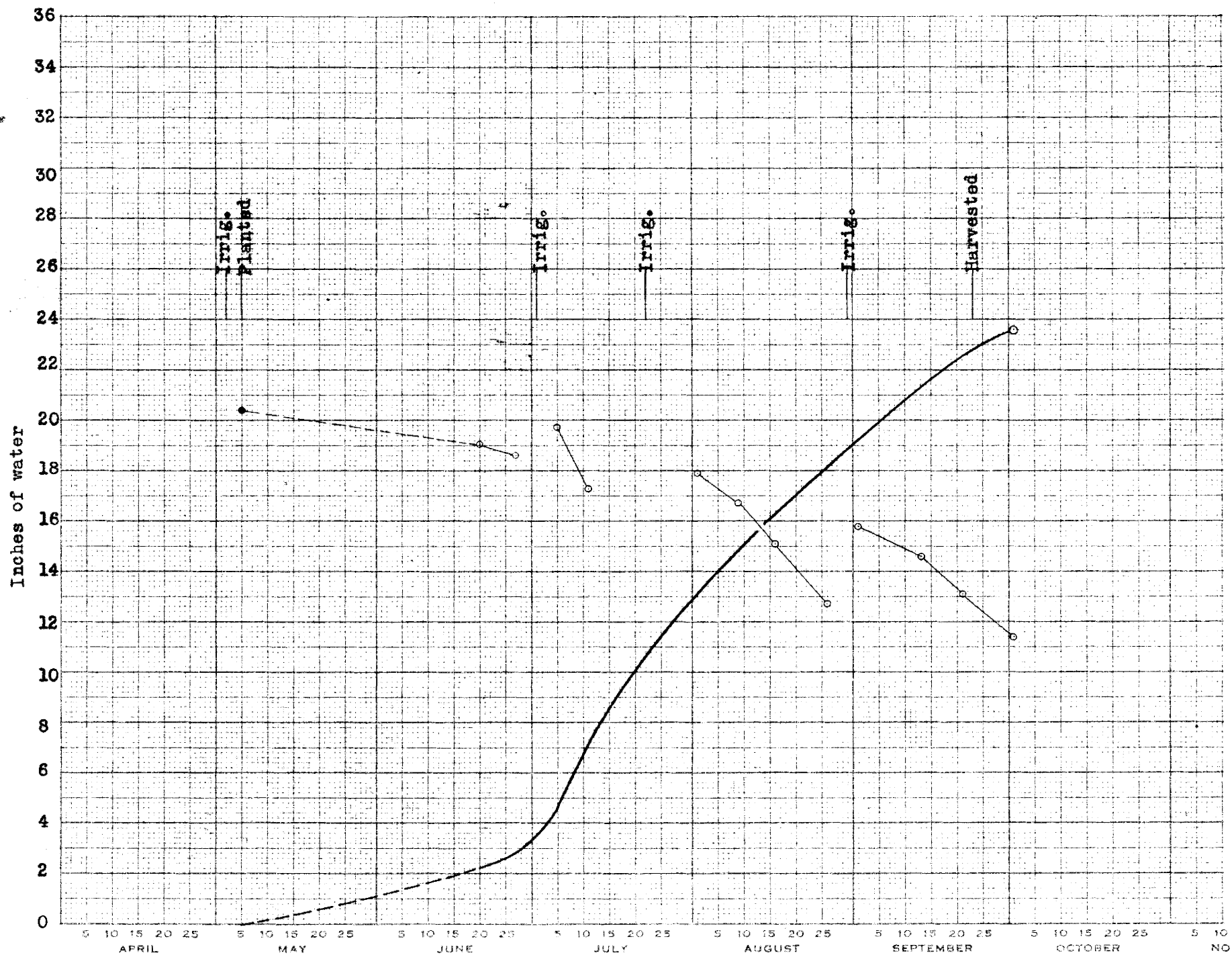


Figure 19 Plot A2c. Consumptive use of water by corn, 1949, Ashley Valley, Utah.

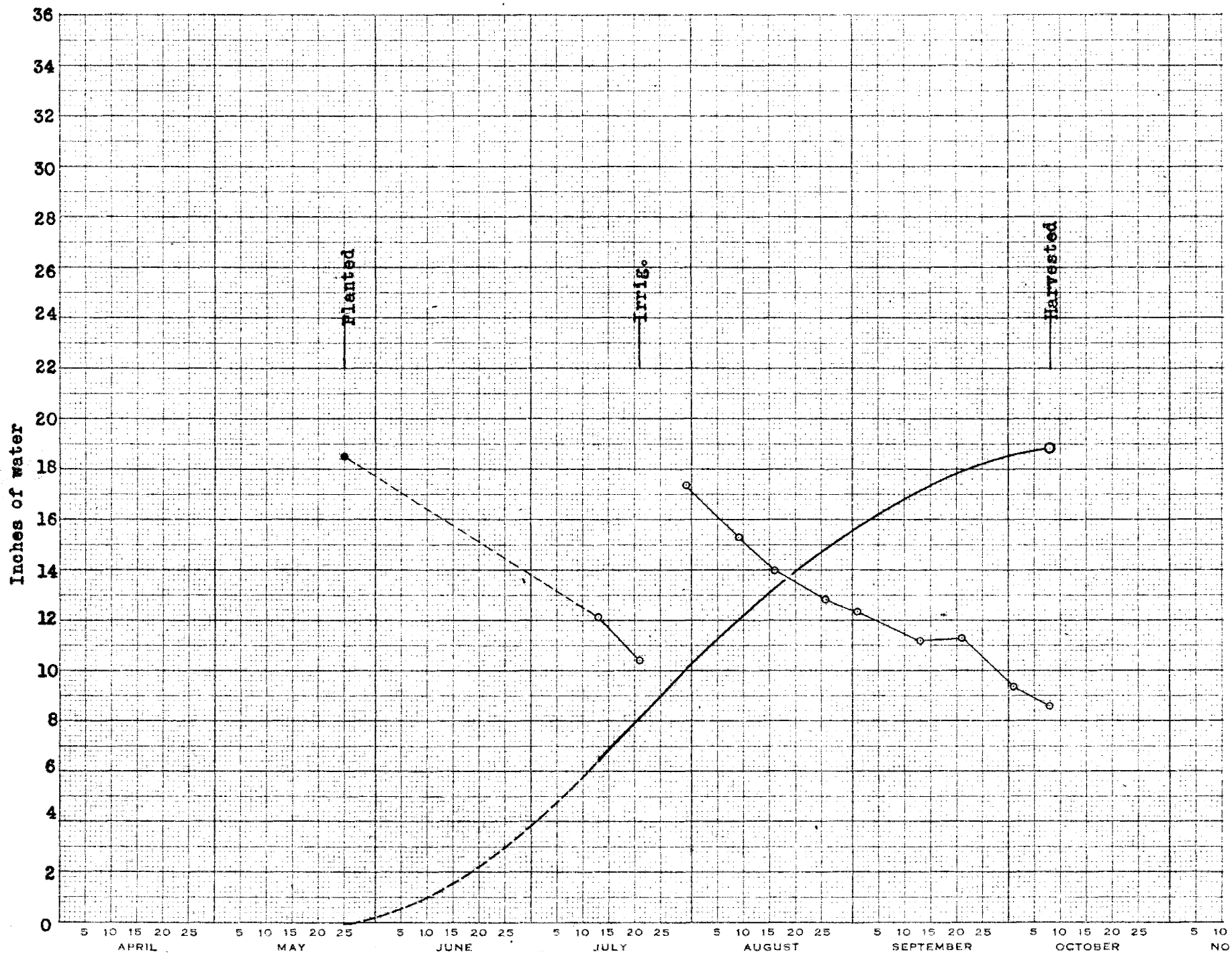


Figure 20 Plot A3c. Consumptive use of water by corn, 1949, Ashley Valley, Utah.



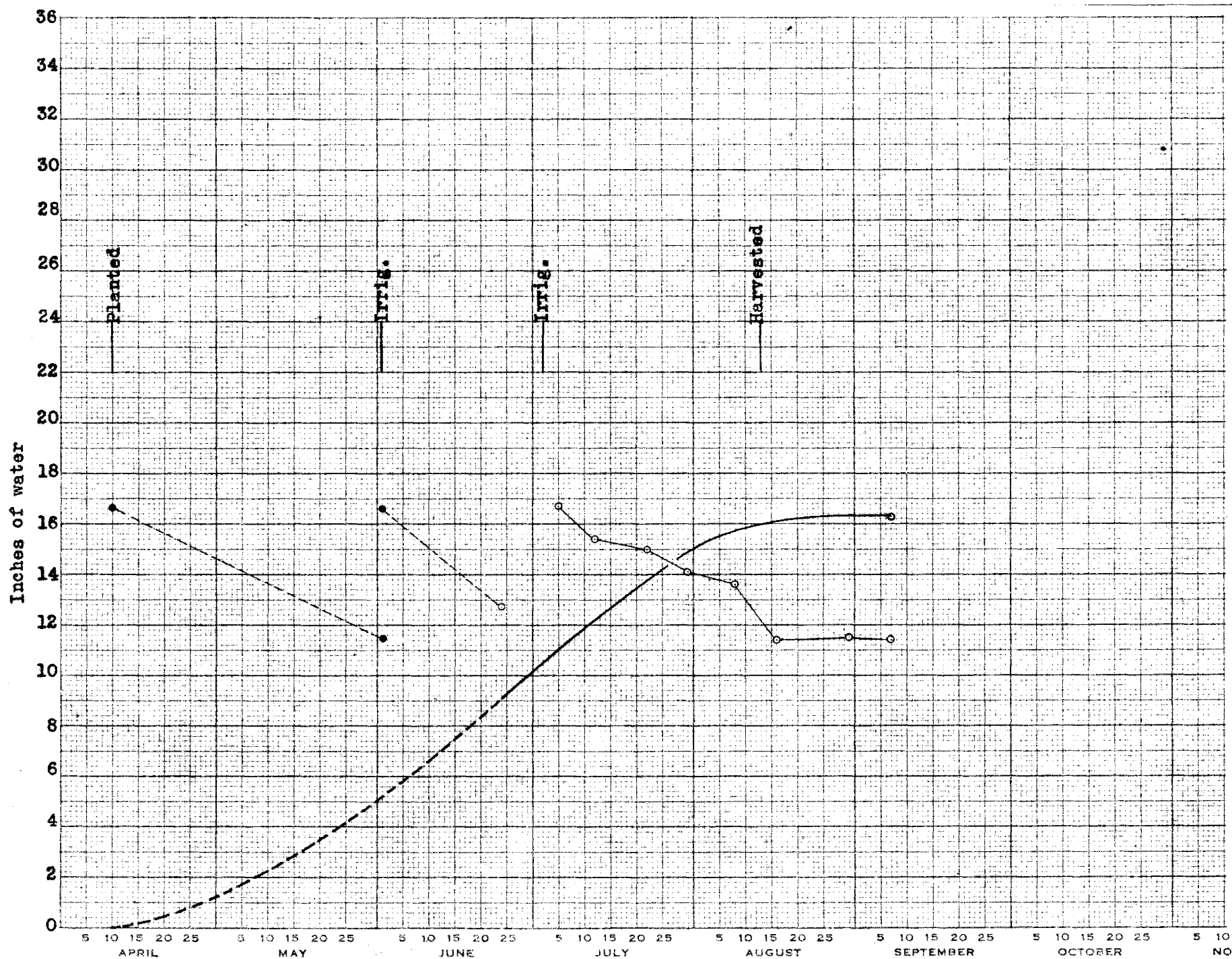


Figure 21 Plot Alw. Consumptive use of water by wheat, 1949, Ashley Valley, Utah.

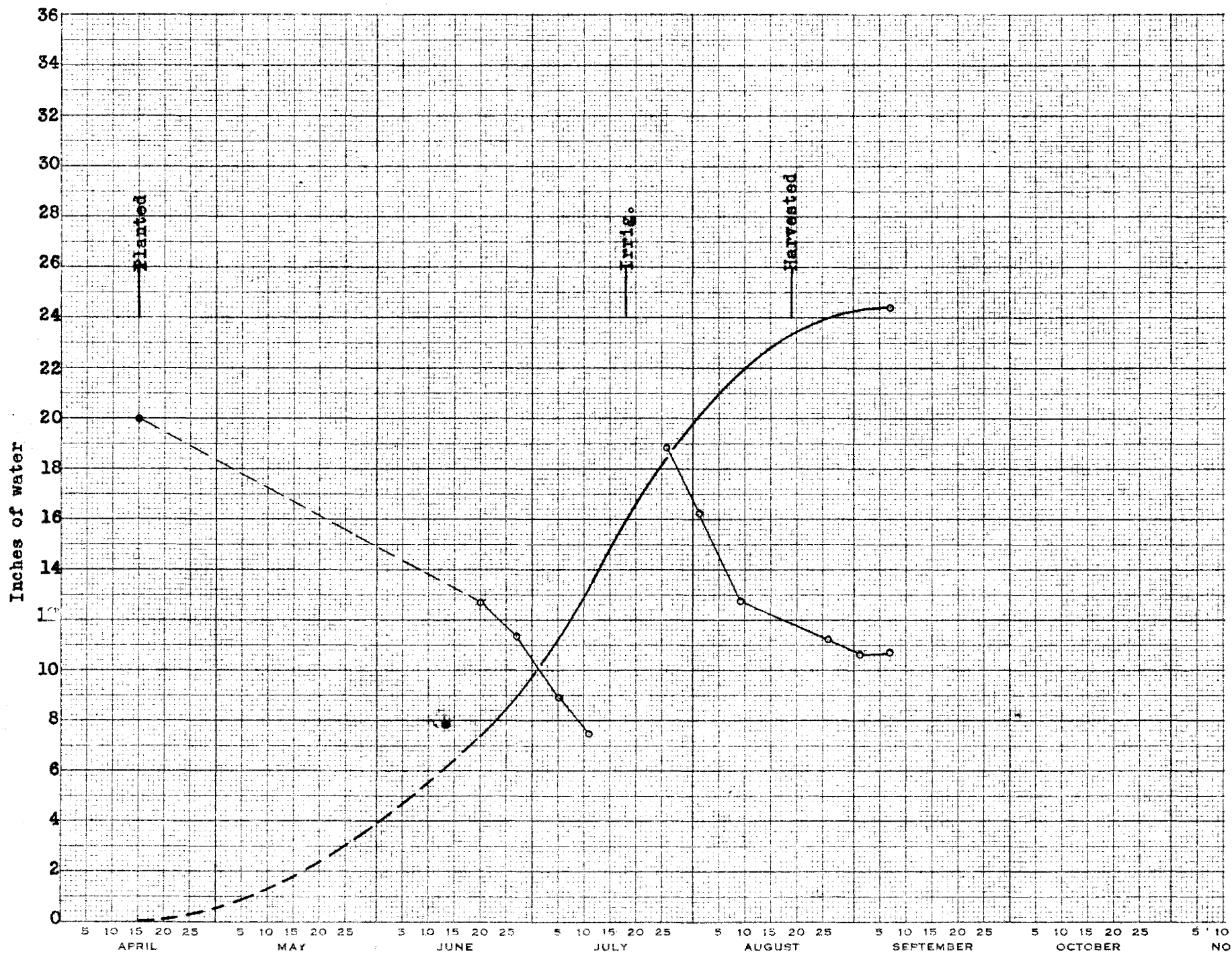


Figure 22 Plot A2w. Consumptive use of water by wheat, 1949, Ashley Valley, Utah.



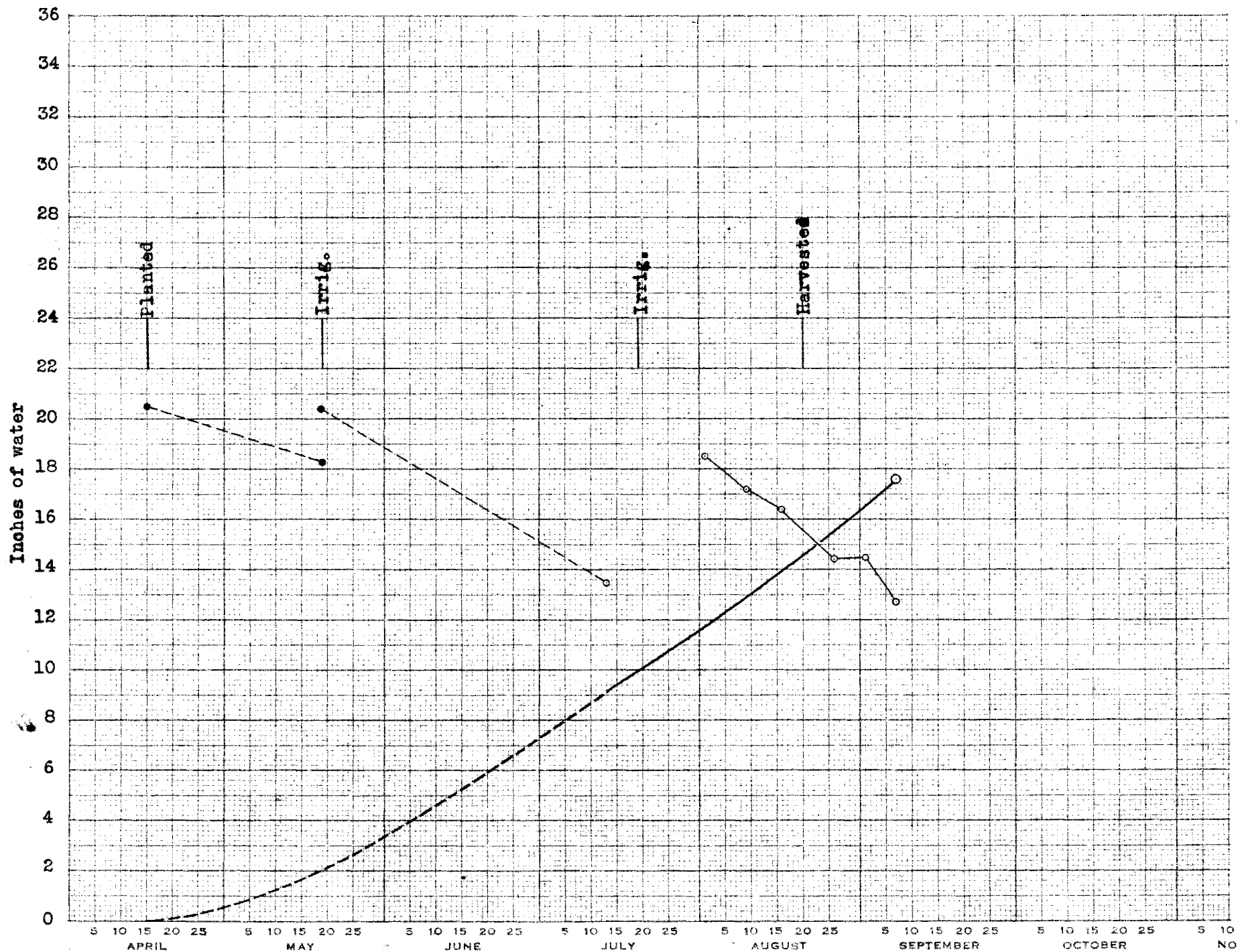


Figure 23 Plot Alo. Consumptive use of water by oats, 1949, Ashley Valley, Utah.

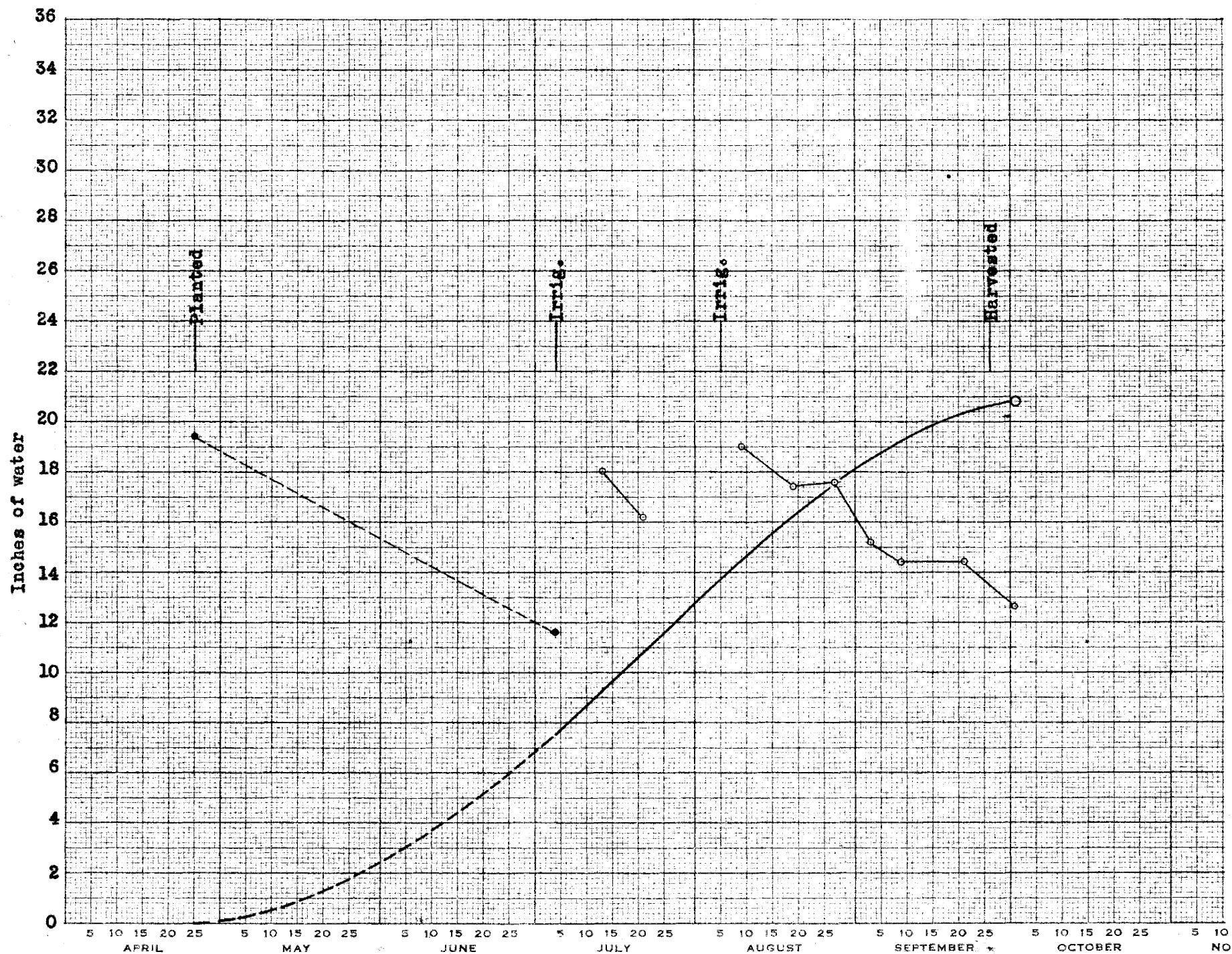


Figure 24 Plot A2o. Consumptive use of water by oats, 1949, Ashley Valley, Utah.

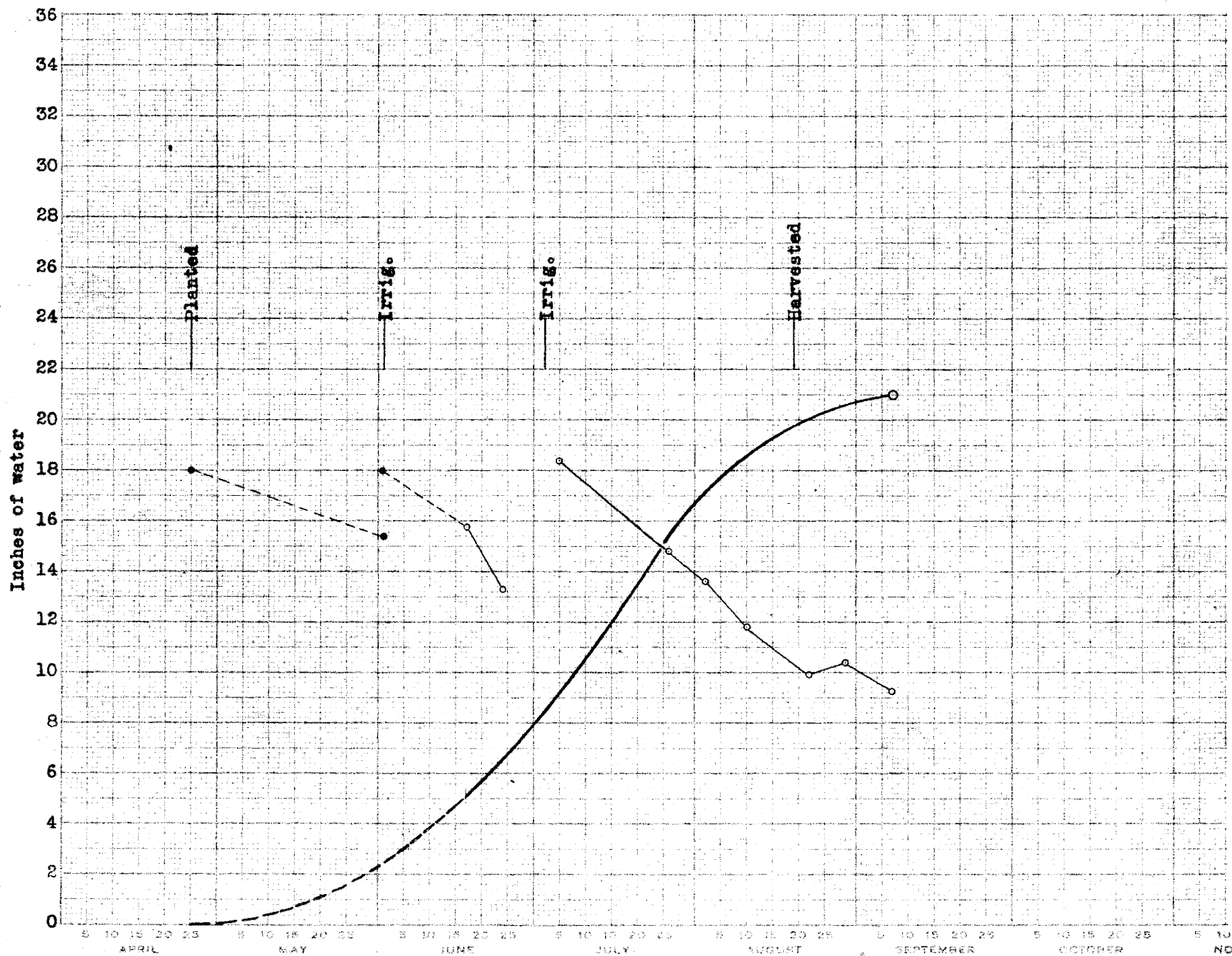


Figure 25 Plot A3o. Consumptive use of water by oats, 1949, Ashley Valley, Utah.

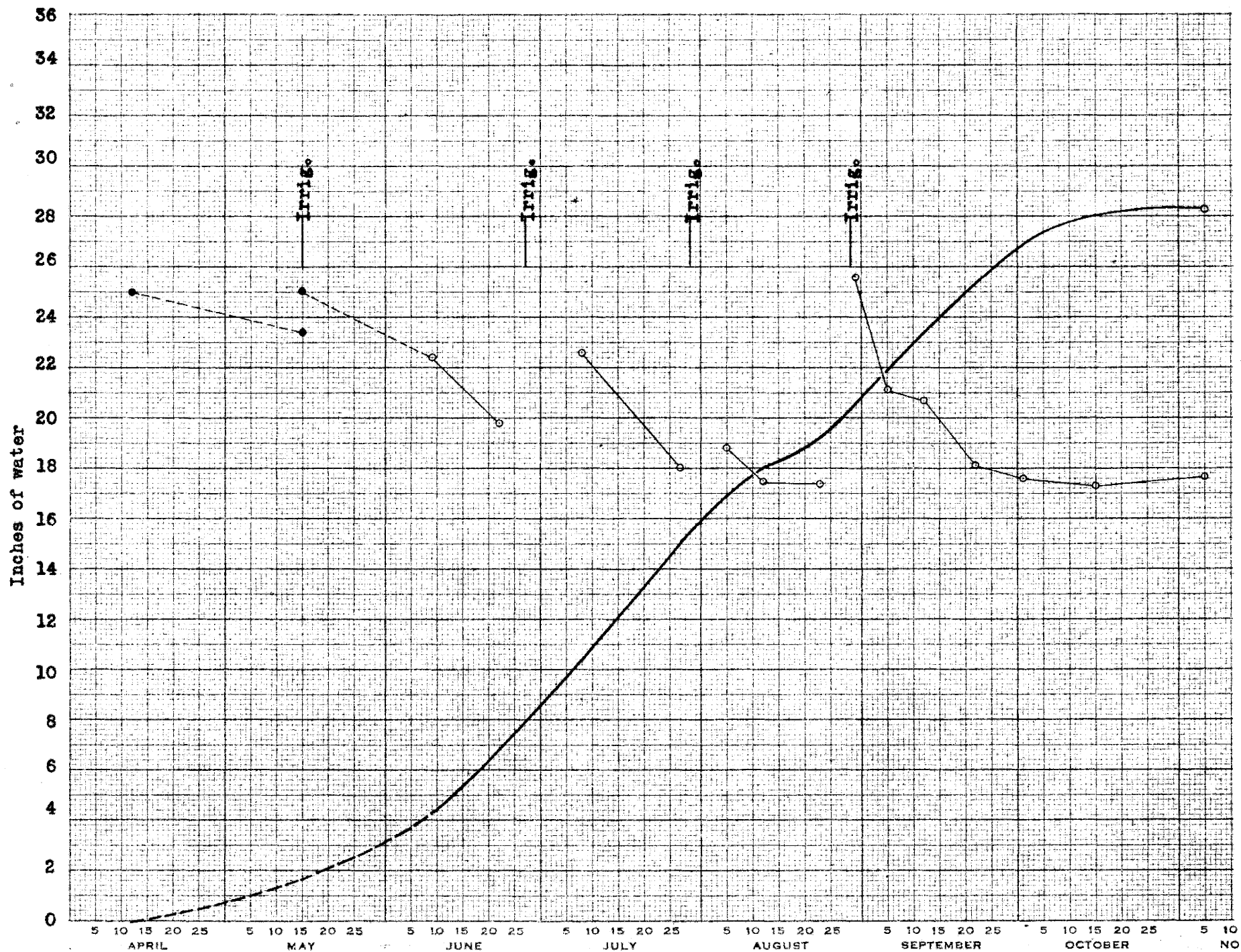


Figure 26 Plot Fla. Consumptive use of water by alfalfa, 1949, Ferron Creek Area, Utah.

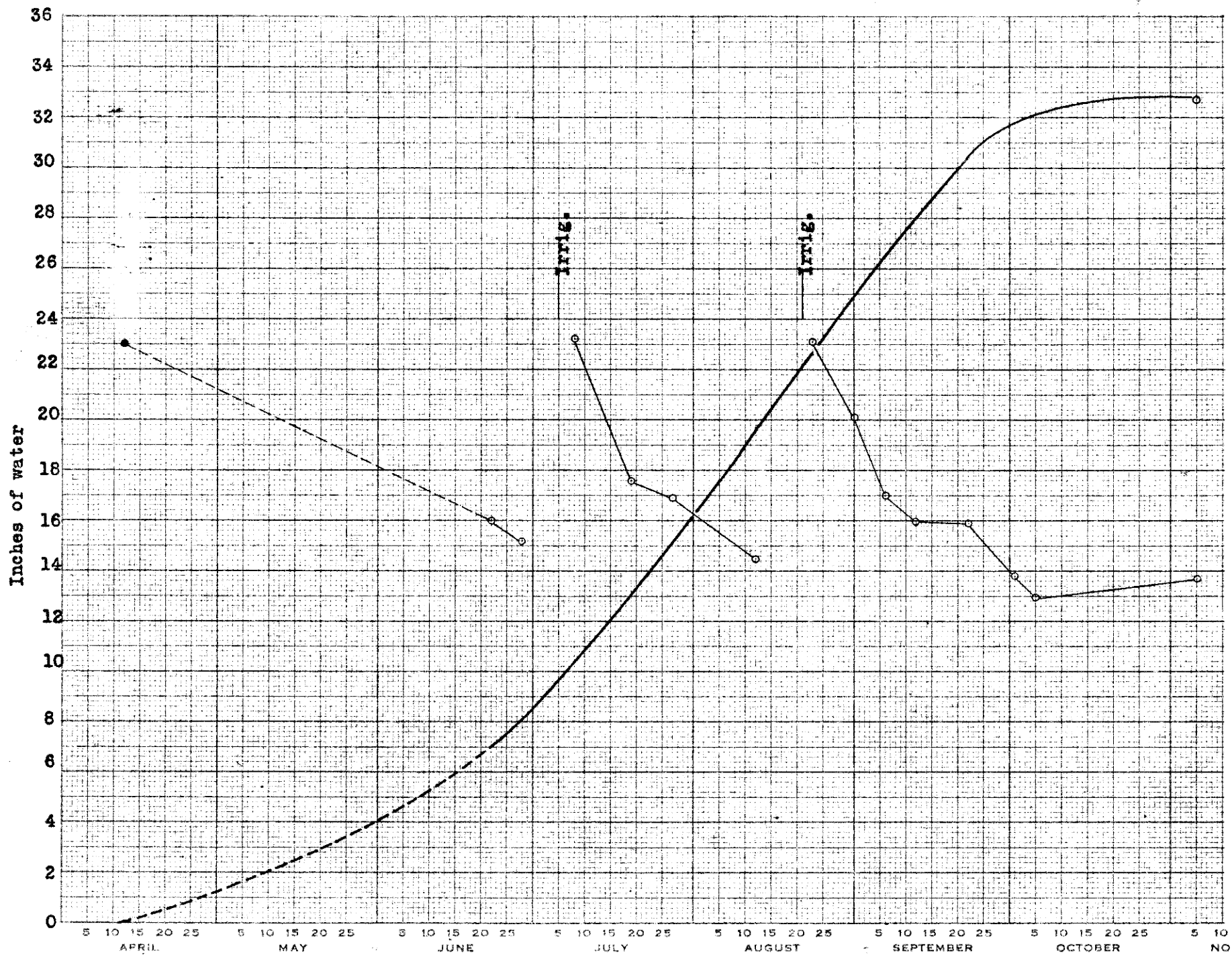


Figure 27 Plot F2a. Consumptive use of water by alfalfa, 1949, Ferron Creek Area, Utah.



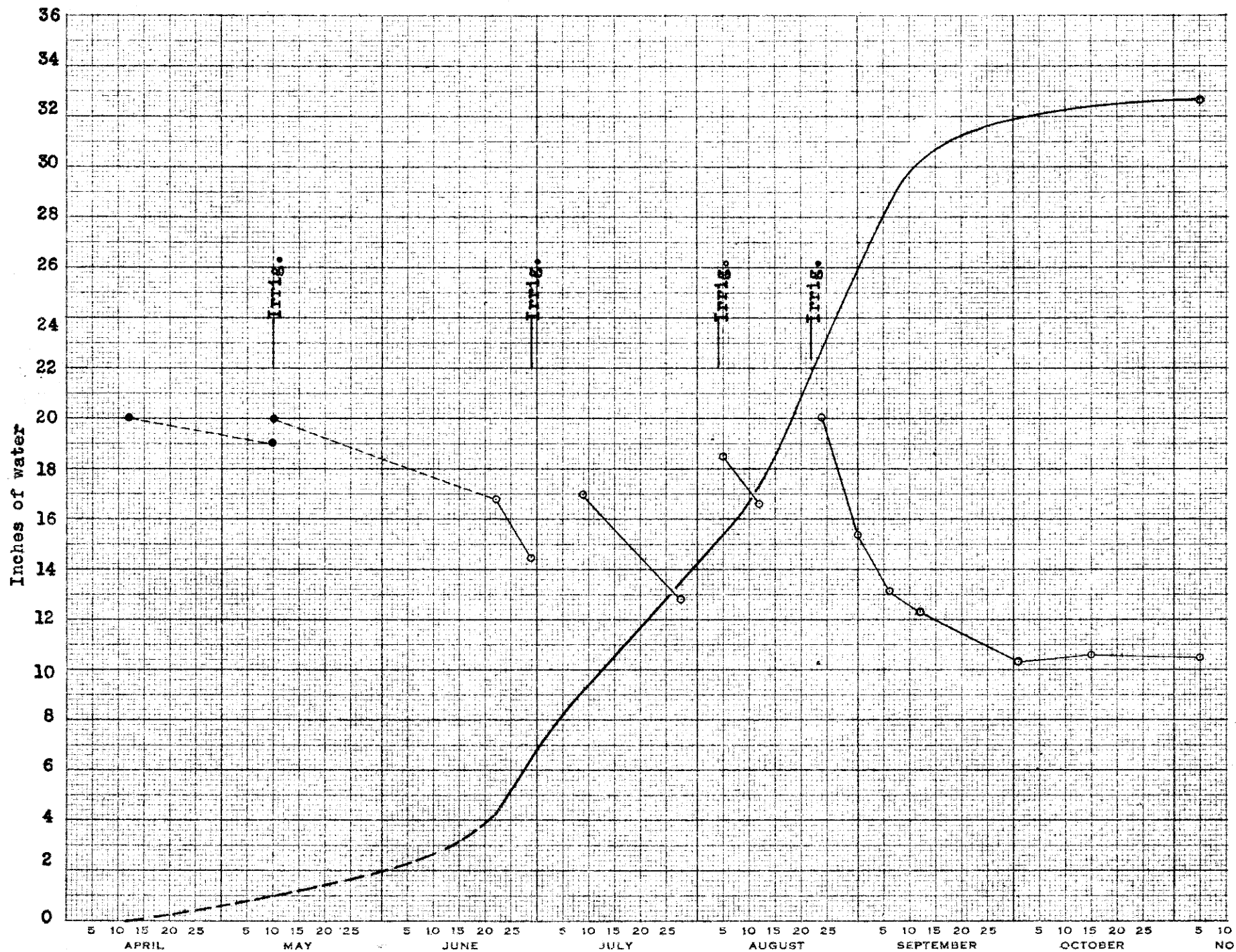


Figure 28 Plot F3a. Consumptive use of water by alfalfa, 1949, Ferron Creek Area, Utah.

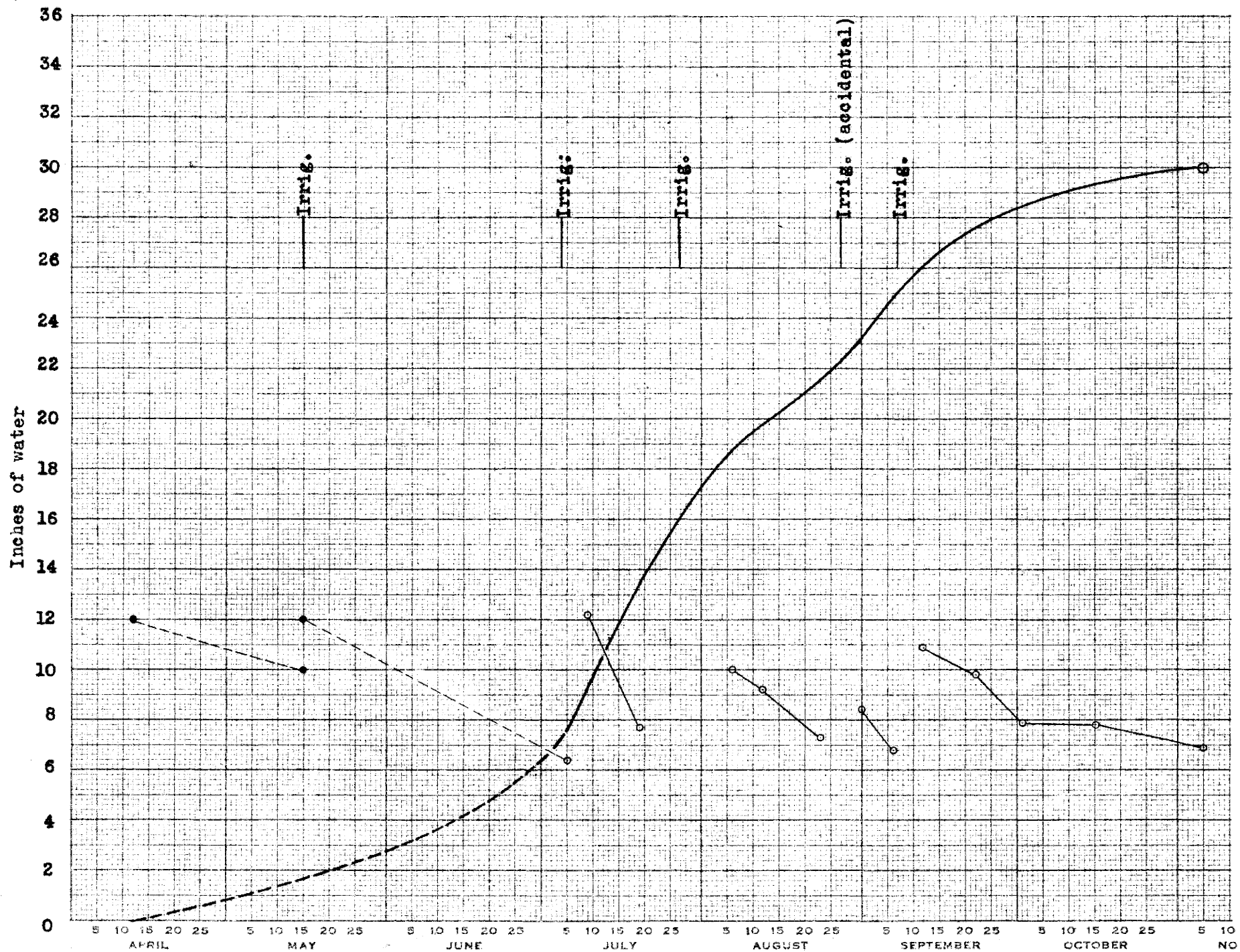


Figure 29 Plot Flp. Consumptive use of water by pasture, 1949, Ferron Creek Area, Utah.

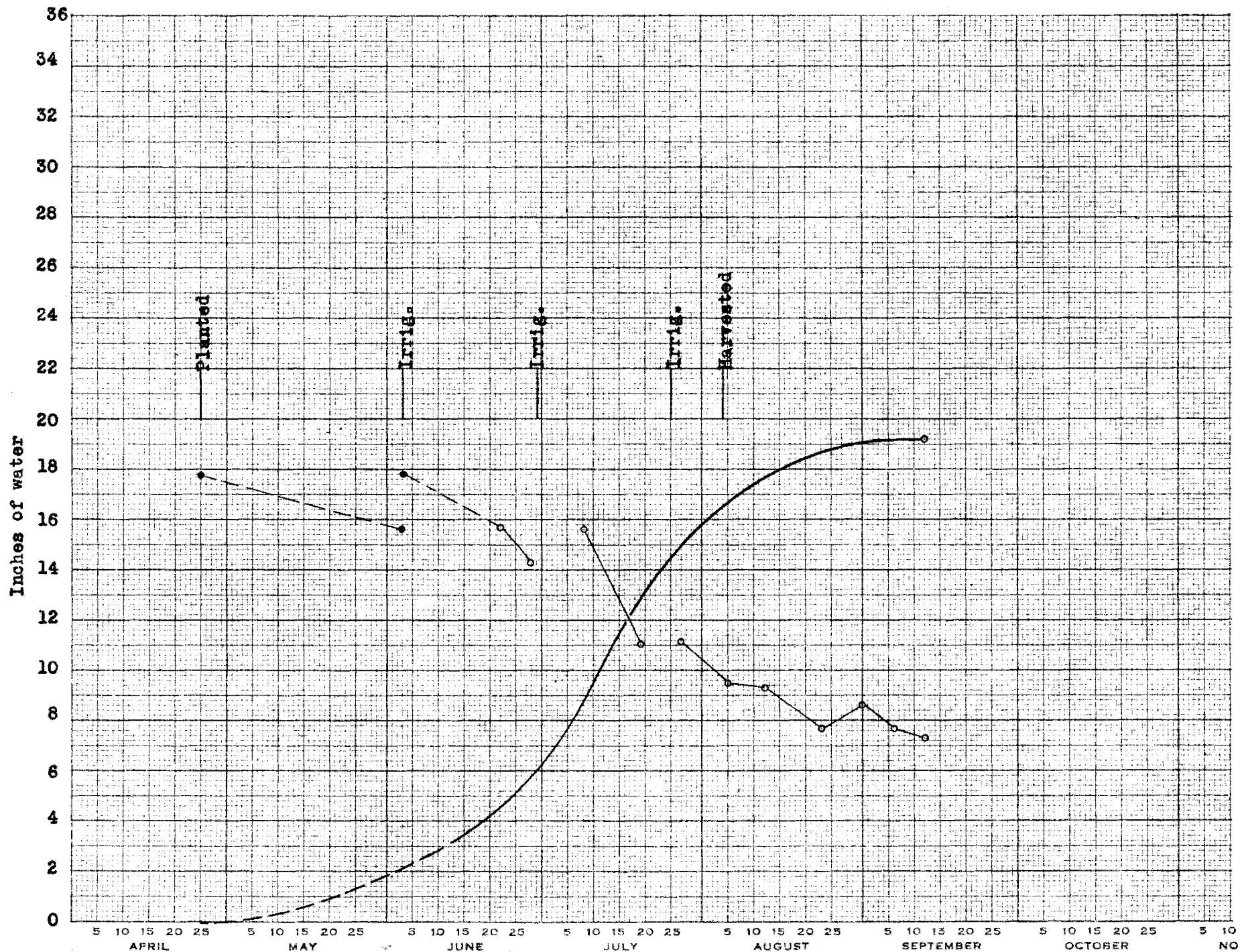


Figure 30 Plot Flb. Consumptive use of water by barley, 1949, Ferron Creek Area, Utah.



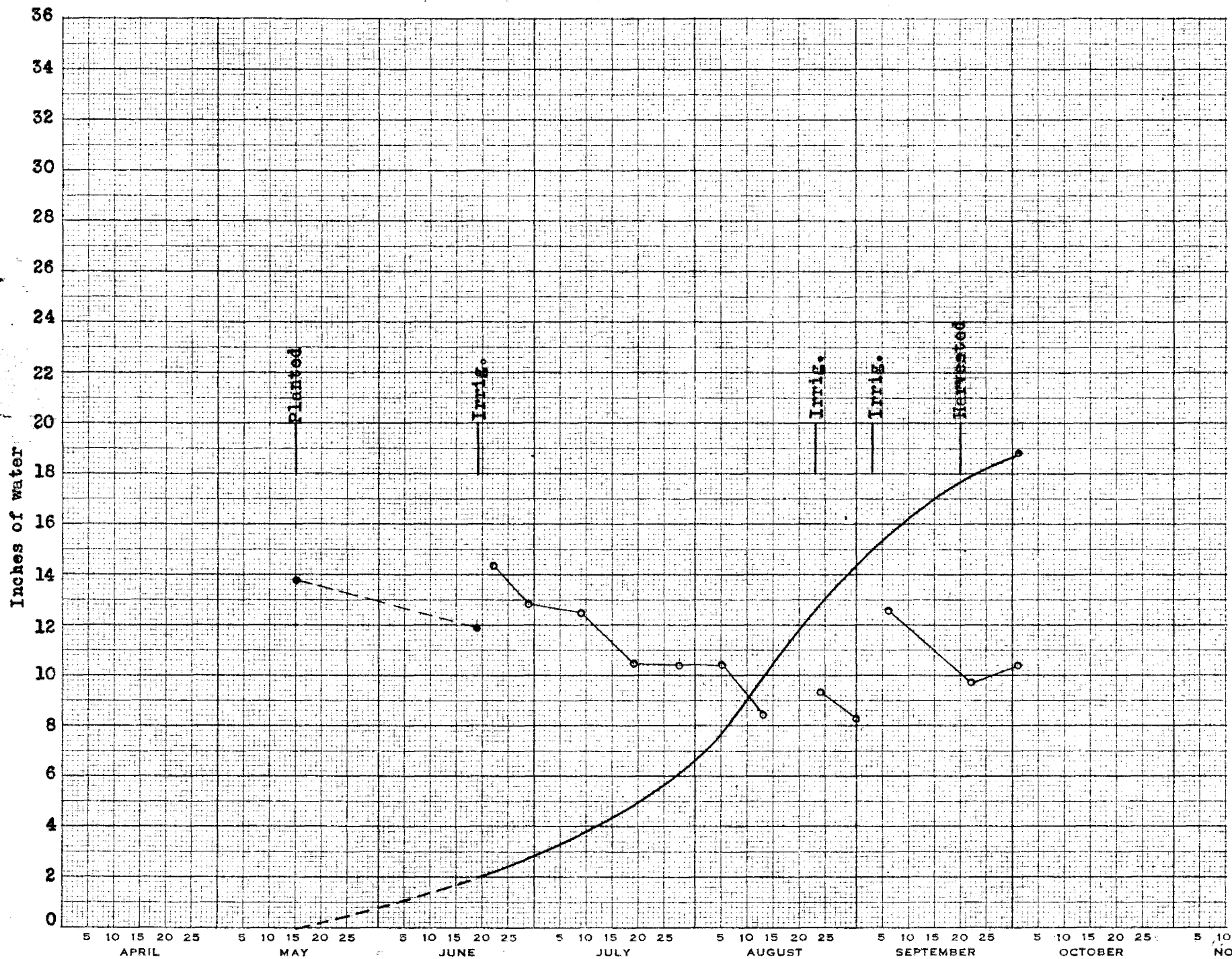


Figure 31 Plot Flc. Consumptive use of water by corn, 1949, Ferron Creek Area, Utah.

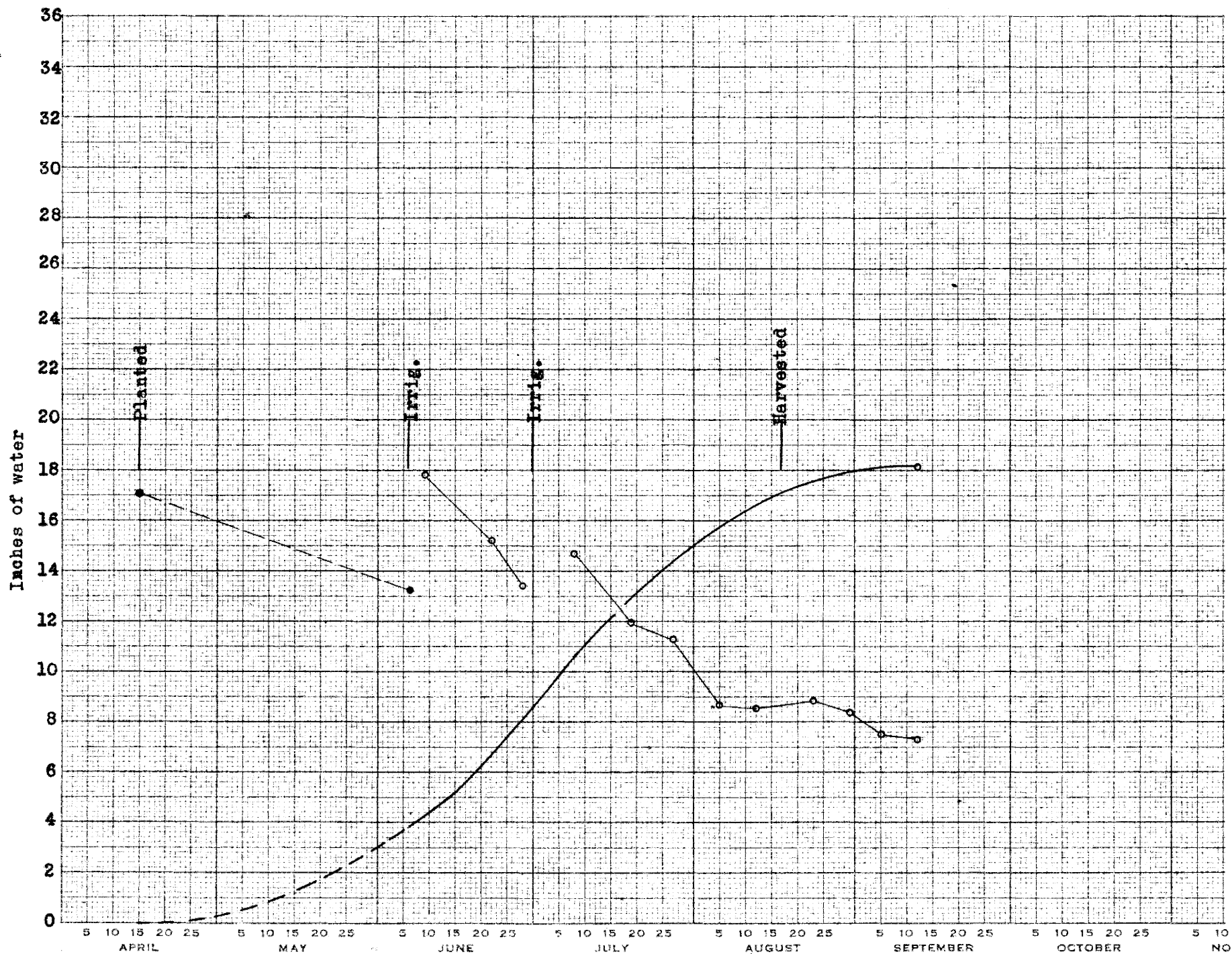


Figure 32 Plot Flw. Consumptive use of water by wheat, 1949, Ferron Creek Area, Utah.

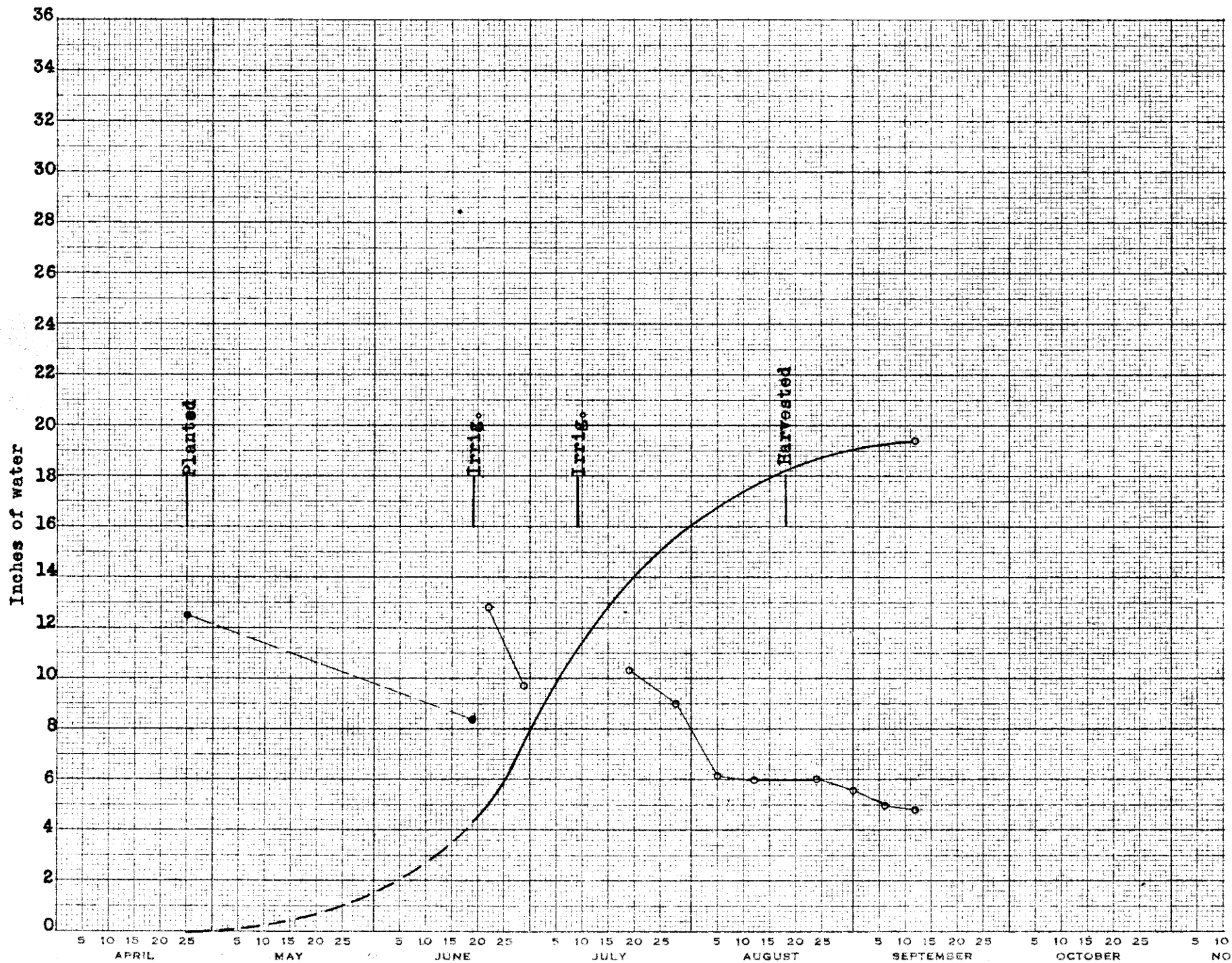


Figure 33 Plot F2w. Consumptive use of water by wheat, 1949, Ferron Creek Area, Utah.

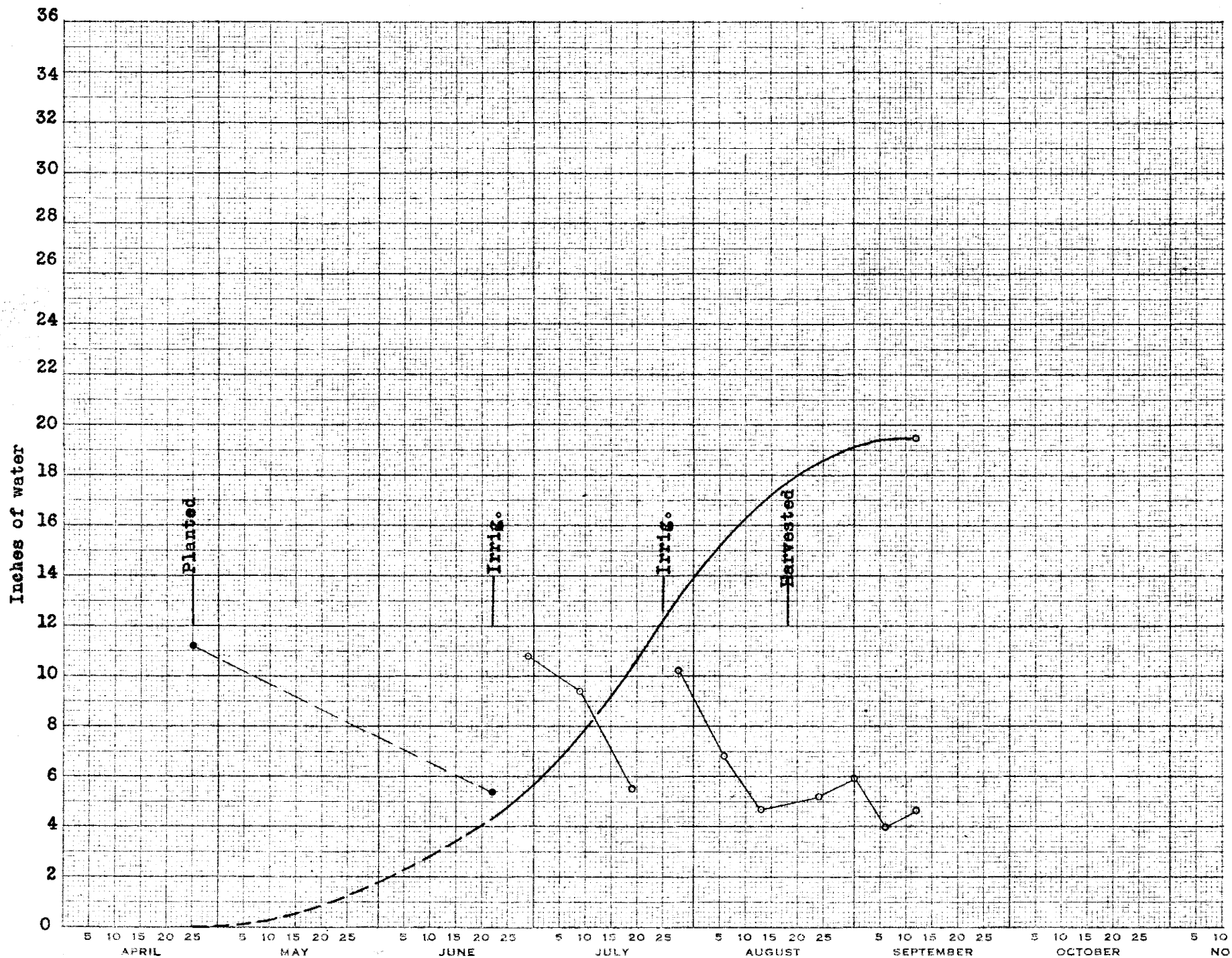


Figure 34 Plot F3w. Consumptive use of water by wheat, 1949, Ferron Creek Area, Utah.